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ASTRONOMY

The Ride Report
NASA

U.S. Space Future
Where Do We Go from Here?

January 1988
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"Several hundred amateurs had the chance to test the performance of Meade Series 4000 eyepieces at the recent Astrofest Telescope Convention. Observing Jupiter with your Ultra Wide 8.8mm on a 7" f/9 Starfire refractor, the huge 84° field encompassed the entire Jovian system. The four moons were resolved as discs, perfectly round even at the extreme edge of the field. Jupiter itself presented a magnificent show with a multitude of bands, small ovals, and festoons, etched in high contrast on the planet's surface. Meade Ultra Wide Angle eyepieces are a unique design that really bring out the best in a high performance telescope."**—Roland Christen, President, Astro-Physics Corp., Rockford, Ill.**

"My experience with Meade Instruments is consistently on a higher level than with other astronomical equipment manufacturers. One Meade product is so outstanding I must comment on it. The Meade Series 4000 eyepieces are clearly the finest eyepieces available. I have owned or used just about every other commercially manufactured Plössl eyepiece, and one does not need to be a seasoned observer to immediately notice the difference." **—Michael Barnett, Westlake Village, Calif.**

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Cover: The appearance of the corona at the onset of totality is a long-awaited sight for eclipse observers. Photo of the June 11, 1983, eclipse in Tuban, Indonesia, by Richard Berry. These pages: European eclipse observers view the June 20, 1984, annular eclipse from Morocco. Photo by Dewey Vanderhoff.

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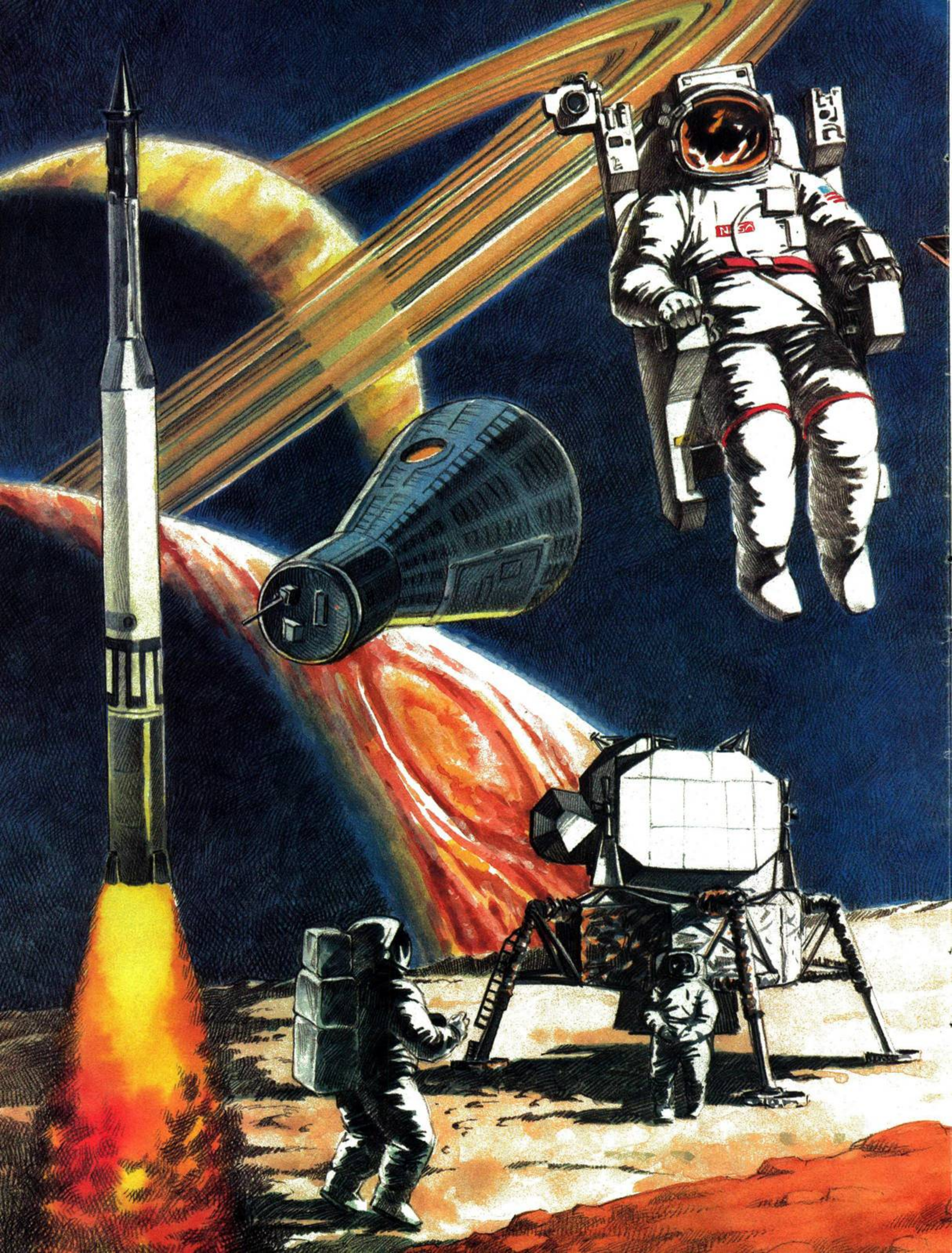
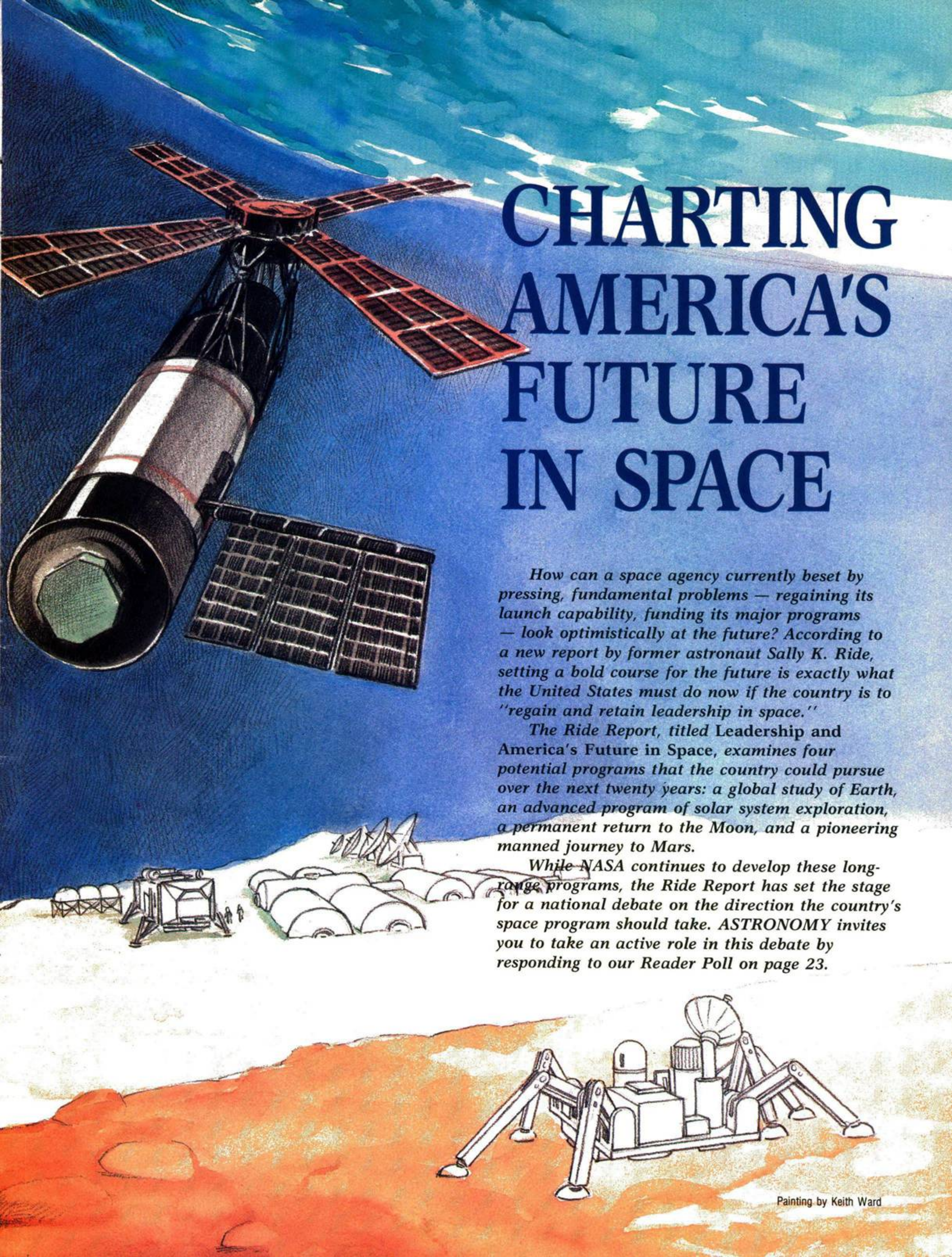




CHARTING AMERICA'S FUTURE IN SPACE

How can a space agency currently beset by pressing, fundamental problems — regaining its launch capability, funding its major programs — look optimistically at the future? According to a new report by former astronaut Sally K. Ride, setting a bold course for the future is exactly what the United States must do now if the country is to "regain and retain leadership in space."

The Ride Report, titled Leadership and America's Future in Space, *examines four potential programs that the country could pursue over the next twenty years: a global study of Earth, an advanced program of solar system exploration, a permanent return to the Moon, and a pioneering manned journey to Mars.*

While NASA continues to develop these long-range programs, the Ride Report has set the stage for a national debate on the direction the country's space program should take. ASTRONOMY invites you to take an active role in this debate by responding to our Reader Poll on page 23.

Painting by Keith Ward

LEADERSHIP AND AMERICA'S FUTURE IN SPACE

by Sally K. Ride

The Ride Report
NASA

For nearly a quarter of a century, the U.S. space program enjoyed what can appropriately be termed a "golden age." From the launch of Earth-orbiting satellites, to the visits by robotic spacecraft to Venus and Mars, to the stunning achievement of landing the first human beings on the Moon, the many successes of the space program were exciting and awe-inspiring. The United States was clearly and unquestionably the leader in space exploration, and the nation reaped all the benefits of pride, international prestige, scientific advancement, and technological progress that such leadership provides.

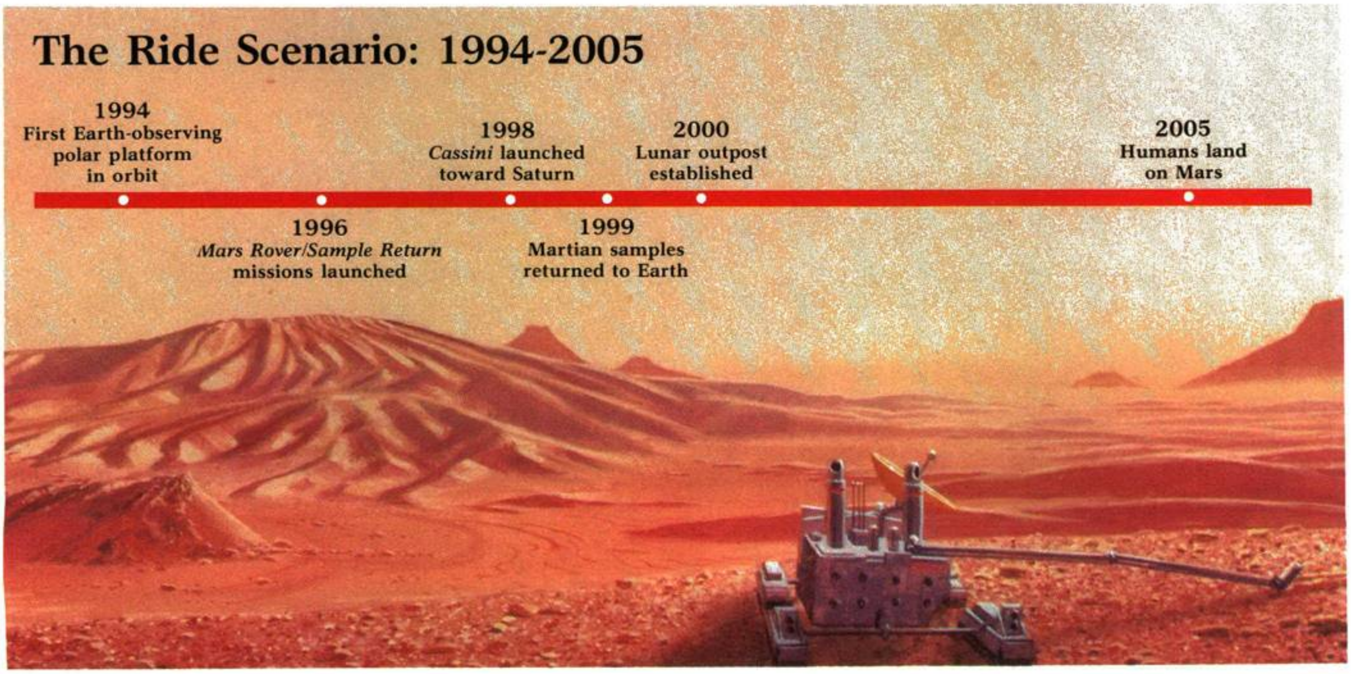
However, in the aftermath of the *Challenger* accident, reviews of our space program made its shortcomings starkly apparent. The United States' role as the leader of the spacefaring nations came into serious question.

The U.S. civilian space program is now at a crossroads, aspiring toward the visions of the National Commission on Space but faced with the realities set forth by the Rogers Commission. NASA must respond aggressively to the challenges of both while recognizing the necessity of maintaining a balanced space program within reasonable fiscal limits. . . .

The goals of the civilian space program must be carefully chosen to be consistent with the national interest and also to be consistent with NASA's capabilities. NASA alone cannot set these goals, but NASA must lead the discussion, present technically feasible options, and implement programs to pursue those goals which are selected.

We must ask ourselves: "Where do we want to be at the turn of the century?" and "What do we have to do now to get there?" Without an eye toward the future, we flounder in the present. . . .

Leadership in space does not require that the U.S. be preeminent in all areas of space enterprise. The widening range of space activities and the increasing number of spacefaring nations make it virtually impossible for any country to dominate in this way. It is, therefore, essential


The Ride Scenario: 1994-2005
1994 First Earth-observing polar platform in orbit
1996 *Mars Rover/Sample Return* missions launched
1998 *Cassini* launched toward Saturn
1999 Martian samples returned to Earth
2000 Lunar outpost established
2005 Humans land on Mars

Abridged from *Leadership and America's Future in Space* by Sally K. Ride (August 1987). The report is available from the U.S. Superintendent of Documents, Washington, D.C. 20402 for $4.

"Without an eye to the future, we flounder in the present."
— Sally K. Ride

for America to move promptly to determine its priorities and to pursue a strategy which would restore and sustain its leadership in the areas deemed important. . . .

Being an effective leader does mandate, however, that this country have capabilities which enable it to act independently and impressively when and where it chooses, and that its goals be capable of inspiring others — at home and abroad — to support them. It is essential for this country to move promptly to determine its priorities and to make conscious choices to pursue a set of objectives which will restore its leadership status. . . .

In response to growing concern over the posture and long-term direction of the U.S. civilian space program, NASA Administrator Dr. James Fletcher formed a task group to define potential U.S. space initiatives, and to evaluate them in light of the current space program and the nation's desire to regain and retain space leadership. The objectives of the study were to energize a discussion of the long-range goals of the civilian space program and to begin to investigate overall strategies to direct that program to a position of leadership.

The task group identified four candidate initiatives for study and evaluation. Each builds on NASA's achievements in science and exploration, and each is a bold, aggressive proposal which would, if adopted, restore the United States to a position of leadership in a particular sphere of space activity. The four initiatives are: (1) Mission to Planet Earth, (2) Exploration of the Solar System, (3) Outpost on the Moon, and (4) Humans to Mars. All four initiatives were developed in detail, and the implications and requirements of each were assessed.

This process was not intended to culminate in the selection of one initiative and the elimination of the other three, but rather to provide four concrete examples which would catalyze and focus the discussion of the goals and objectives of the civilian space program and the efforts required to pursue them. . . .

A U.S. space leadership program must have two distinct attributes. First, it must contain a sound program of scientific research and technology development — a program that builds the nation's understanding of space and the space environment, and that builds its capabilities to explore and operate in that environment. The United States will not be a leader in the 21st Century if it is dependent on other countries for access to space or for the technologies required to explore the space frontier. Second, the program must incorporate visible and significant accomplishments; the United States will not be perceived as a leader unless it accomplishes feats which demonstrate prowess, inspire national pride, and engender international respect and a worldwide desire to associate with U.S. space activities. . . .

The next step in this process should be to articulate specific objectives and to identify the programs required to achieve these objectives. . . . Does this country intend to establish a lunar outpost? To send an expedition to Mars? What are NASA's major objectives for the late 20th and early 21st Centuries? The Space Shuttle and Space Station will clearly support the objectives, but what will they be supporting?

These questions cannot, of course, be answered by NASA alone. But NASA should lead the discussion, propose technically feasible options, and make thoughtful recommendations. The choice of objectives will shape, among other things, NASA's technology program, the evolution of the Space Station, and the character of Earth-to-orbit transportation. . . .

The ground rules for this study are important to understand, since they influenced the detailed definition of the initiatives. The ground rules, set forward at the outset of this study, were:

- The initiatives should be considered *in addition* to currently planned NASA programs. They were not judged against, nor would they supplant, existing programs.
- Each initiative should be developed independently. There is, of course, considerable synergism between certain initiatives. For example, one possible progression for human exploration could be the development of a lunar outpost, followed by an expedition to Mars. However, in order to provide a clear starting point for discussion, the four were considered to be distinct.
- The initiatives should achieve major milestones within two decades.
- The Humans to Mars initiative should be assumed to be an American venture. It was beyond the scope of this work to consider joint U.S./Soviet human exploration.

The candidate initiatives were developed and presented to NASA management to: (1) evaluate the initiatives and their implications, and (2) promote a discussion of the attributes of each initiative to determine the elements which are most important to NASA and to the United States.

MISSION TO PLANET EARTH

Mission to Planet Earth is an initiative to understand our home planet, how forces shape and affect its environment, how that environment is changing, and how those changes will affect us. The goal of this initiative is to obtain a comprehensive scientific understanding of the entire Earth System, by describing how its various components function, how they interact, and how they may be expected to evolve on all time scales. . . .

With the launch of the first experimental satellites in the 1960s, NASA pioneered the remote sensing of Earth from space. Over the past two decades, the scientific community has concluded that Earth is in a process of global change, and scientists now believe that it is necessary to study Earth as a synergistic system. . . . Interactive physical, chemical, and biological processes connect the oceans, continents, atmosphere, and biosphere of Earth in a complex way. Oceans, ice-covered regions, and the atmosphere are closely linked and shape Earth's climate; volcanism links inner Earth with the atmosphere; and biological activity significantly contributes to the cycling of chemicals (e.g., carbon, oxygen, and carbon dioxide) important to life. And now it is clear that human activity also has a major impact on the evolution of the Earth System.

Global-scale changes of uncertain impact, ranging from an increase in the atmospheric warming gases, carbon dioxide and methane, to a hole in the ozone layer over the Antarctic, to important variations in vegetation covers and in coastlines, have already been observed with existing measurement capabilities. The potentially major consequences, either detrimental or beneficial, suggest an urgent need to understand these variations.

We currently lack the ability to foresee changes in the Earth System, and their subsequent effects on the planet's physical, economic, and social climate. But that could change; this initiative would revolutionize our ability to characterize our home planet, and would be the first step toward developing predictive models of the global environment.

The guiding principle behind this initiative is to adopt an integrated approach to observing Earth. The observations from various sensors on platforms and satellites will be coordinated to perform global surveys and also to perform detailed observations of specific phenomena.

Mission to Planet Earth proposes:

1. To establish and maintain a global observational system in space, which would include experiments and free-flying platforms, in polar, low-inclination, and geostationary orbits, and which would perform integrated, long-term measurements.
2. To use the data from these satellites along with *in-situ* information and numerical modeling to document, understand, and eventually predict global change.

The global observational system would include a suite of nine orbiting platforms:

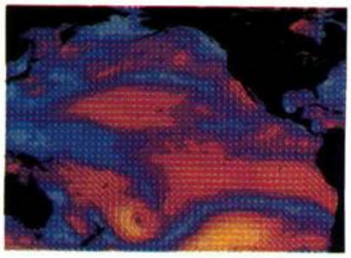
- Four sun-synchronous polar platforms: two provided by the United States and one each provided by the European Space Agency (ESA) and the Japanese National Space Development Agency (NASDA). The first platform would be launched in 1994 and all four platforms would be in orbit by 1997. These platforms would provide global polar coverage with morning and afternoon crossing times.
- Five geostationary platforms: three provided by the U.S. and one each by ESA and NASDA. These platforms would all be launched and deployed between 1996 and 2000. . . .

The integrated system would measure the full complement of the planet's characteristics, including: global cloud cover, vegetation cover, and ice cover; global rainfall and moisture; ocean chlorophyll content and ocean topography; motions and deformations of Earth's tectonic plates; and atmospheric concentration of gases such as carbon dioxide, methane, and ozone.

Space-based observations would also be coordinated with ground-based experiments and the data from all observations would be integrated by an essential component of this initiative: a versatile, state-of-the-art information management system. This tool is critical to data analysis and numerical modeling, and would enable the integration of all observational data and the development of diagnostic and predictive Earth System models. . . .

To achieve its full scope, this initiative requires the operational support of Earth-to-orbit and space transportation systems to accommodate the launching of polar and geostationary platforms. This does not represent a large number of additional launches, but it does require the capability to launch large payloads to polar orbit; Titan IVs would be used to accomplish this. Since the envisioned geostationary platforms would be lifted to low-Earth orbit, assembled at the Space Station, and then lifted to geosynchronous orbit with a space transfer vehicle, well-developed orbital facilities are essential. By the late

"Do we dare apply our capabilities to explore the mysteries of other worlds, and not also explore the mysteries of our own?"


Global wind patterns

1990s, the Space Station must be able to support on-orbit assembly, and a space transfer vehicle must exist. . . .

Mission to Planet Earth is not the sort of major program the public normally associates with an agency famous for *Apollo*, *Viking*, and *Voyager*. But this initiative is a great one, not because it offers tremendous excitement and adventure, but because of its fundamental importance to humanity's future on this planet. . . .

The U.S. is the only country currently capable of leading a Mission to Planet Earth, but the program is designed around, and requires, international cooperation. Admittedly, the initiative's international scope could complicate its coordination and implementation, but the concept embodied in the initiative enjoys widespread international support. As more and more countries are facing ecological problems, there is increasing interest in a global approach. . . .

NASA should embrace Mission to Planet Earth. This initiative is responsive, time-critical, and shows a recognition of our responsibility to our home planet. Do we dare apply our capabilities to explore the mysteries of other worlds, and not also to apply those capabilities to explore and understand the mysteries of our own world — mysteries which may have important implications for our future on this planet?

EXPLORATION OF THE SOLAR SYSTEM

This initiative would build on NASA's long-standing tradition of solar system exploration and would continue the quest to understand our planetary system, its origin, and its evolution. Solar system bodies are divided into three distinct classes: the primitive bodies (comets and asteroids), the outer (gas giant) planets, and the inner (terrestrial) planets. Each class occupies a unique position in the history of the solar system, and each is a target of a major mission in this initiative, which includes a comet rendezvous (the *Comet Rendezvous Asteroid Flyby* mission), a mission to Saturn (*Cassini*), and three sample return missions to Mars. The centerpiece of the initiative is the robotic exploration of Mars; the first of these three automated missions would bring a handful of Mars back to Earth before the year 2000. . . .

Although currently scheduled U.S. missions will ensure that the United States will remain a leader in certain areas of solar system exploration through 1995, the position of the United States beyond 1995 is in question. This initiative would maintain U.S. leadership in exploration of the outer planets, and would regain and sustain U.S. leadership in the exploration of both the planet Mars and the primitive bodies of the solar system.

This initiative is based on the balanced strategy developed by the Solar System Exploration Committee of the NASA Advisory Council. . . . The missions include:

1. The *Comet Rendezvous Asteroid Flyby* (*CRAF*) mission would investigate the beginnings of our solar system, studying a Main Belt asteroid and a comet, which represent the best-preserved samples of the early solar system. Because of their primordial nature, comets can provide critical clues about the processes that led to the origin and evolution of our solar system.

The *CRAF* mission scenario [begins with] a 1993 launch and a six-month cruise. The spacecraft would fly past the asteroid Hestia at an altitude of about 10,000 kilometers. *CRAF*'s visual and infrared asteroid imaging systems would conduct investigations of Hestia's surface composition and structure. *CRAF* would then continue its journey for a rendezvous with a periodic comet, Tempel 2. The spacecraft would maneuver to within 25 kilometers of the comet's nucleus and begin a series of observations, which includes shooting two penetrators into the nucleus itself for detailed *in-situ* measurements. The spacecraft would fly in close formation with the comet until it nears the Sun and becomes active; then the spacecraft would maneuver farther away to observe the comet's coma and tail.

2. The *Cassini* mission would explore Saturn and its largest moon, Titan. The giant outer planets offer us an opportunity to address key questions about their internal structures and compositions through detailed studies of their atmospheres. Titan is an especially interesting target for exploration because the organic chemistry now taking place there provides the only planetary-scale laboratory for studying processes that may have been important in the prebiotic terrestrial atmosphere.

The *Cassini* mission proposed in this initiative would be a considerably expanded version of the *Cassini* mission considered by the Solar System Exploration Committee. This expanded mission would be launched in 1998 for the long interplanetary voyage to arrive at Saturn in 2005 with a full array of investigative instruments. An orbital spacecraft and three probes would conduct a comprehensive three-year study of the planet and its rings, satellites, and magnetosphere. One atmospheric probe would be launched toward Titan. The expanded *Cassini* mission would also carry one probe to investigate the Saturnian atmosphere, and one semi-soft lander which would reach the surface of Titan.

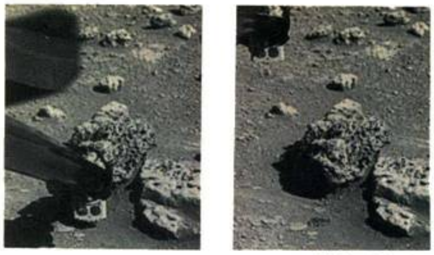
3. The *Mars Rover/Sample Return* mission would, in journeys covering hundreds of millions of miles, gather samples of Mars and bring them back to Earth. Because of its relevance to understanding Earth and other terrestrial planets, and because it is the only other potentially habitable planet in our solar system, Mars is an intriguing target for exploration.

The *Mars Rover/Sample Return* mission scenario would involve a soft landing on the Martian surface, deployment of a "smart" surface rover to select and collect samples, delivery of the samples to an ascent vehicle, and transfer of the samples from Mars orbit to a return vehicle. The samples would then most likely be returned to a sample-handling module on the Space Station for analysis.

The initiative would include three such missions: two launched in 1996, probably sending redundant rovers and ascent vehicles to ensure return of a sample in 1999, and one launched in 1998/99 with return in 2001.

As it is defined, this initiative places a premium on advanced technology and enhanced launch capabilities to maximize the scientific return. It requires aerobraking

"Although current missions ensure that the United States remains a leader in certain areas of exploration through 1995, our position beyond that is in question."



Viking 2 lander

technology for aerocapture and aeromaneuvering at Mars, and a high level of sophistication in automation, robotics, and sampling techniques. Advanced sampling methods are necessary to ensure that geologically and chemically varied and interesting samples are collected for analysis.

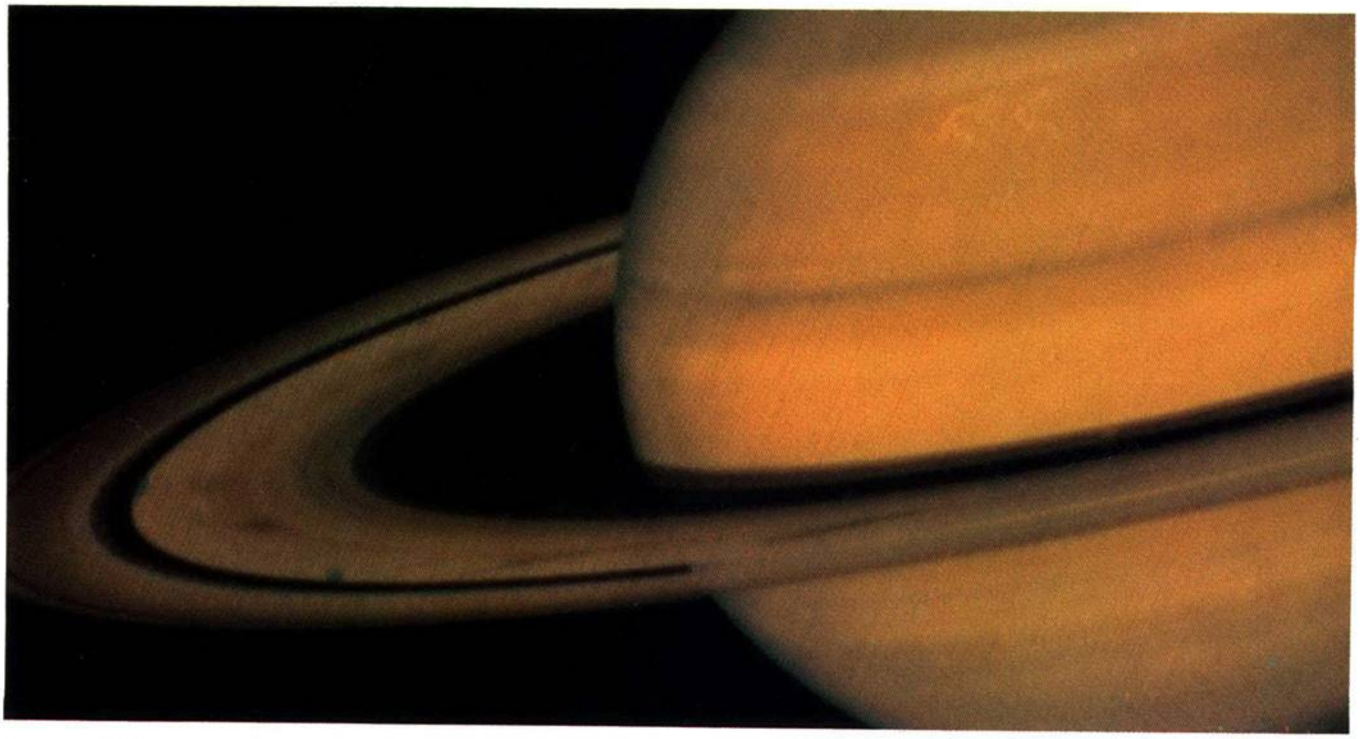
The Solar System Exploration initiative significantly benefits from improved launch capability in terms of the science returned from both the Mars and *Cassini* missions. In fact, it is a heavy-lift launch vehicle that enables the full complement of three different probes to be carried in the expanded *Cassini* mission.

The Space Shuttle is not required for any of the missions in the initiative. The Space Station would not be needed until 1999, when an isolation module may be used to receive the Martian samples. . . .

Although the *Mars Rover/Sample Return* was presented as a U.S. mission in this initiative, it could be performed in cooperation with our allies and/or in coordination with the Soviet Union. . . .

Robotic planetary exploration should be actively supported and nurtured within NASA. Although it does not have the immediate relevance of the Mission to Planet Earth, or the excitement of human exploration, it is fundamental science that challenges our technology, extends our presence, and gives a glimpse of other worlds. As such, it enjoys widespread public interest and support. Although not necessarily at the pace suggested in this initiative, planetary exploration must be solidly supported through the 1990s.

Comet Halley (Caltech photo)



OUTPOST ON THE MOON

This initiative builds on the legacy of *Apollo* and envisions a new phase of lunar exploration and development — a phase leading to a human outpost on another world. That outpost would support scientific research and exploration of the Moon's resource potential, and would represent a significant extraterrestrial step toward learning to live and work in the hostile environments of other worlds.

Beginning with robotic exploration in the 1990s, this initiative would land astronauts on the lunar surface in the year 2000, to construct an outpost that would evolve in size and capability and would be a vital, visible extension of our capabilities and our vision. . . .

This initiative represents a sustained commitment to learn to live and work in space. As our experience and capabilities on the lunar surface grow, this extraterrestrial outpost will gradually become less and less dependent on the supply line to Earth. The first steps toward "living off the lunar land" will be learning to extract oxygen from the lunar soil, where it is plentiful, and learning to make construction materials. The lunar soil would eventually be a source of oxygen for propellant and life-support systems, and a source of material for shelters and facilities.

The Moon's unique environment provides the opportunity for significant scientific advances; the prospect for gains in lunar and planetary science is abundantly clear. Additionally, since the Moon is seismically stable and has no atmosphere, and since its far side is shielded from the radio noise from Earth, it is a very attractive spot for experiments and observations in astrophysics, gravity wave physics, and neutrino physics, to name a few. It is also an excellent location for materials science and life science research because of its low gravitational field (one-sixth of Earth's).

This initiative proposes the gradual, three-phase evolution of our ability to live and work on the lunar surface.

Phase I: Search for a Site (1990s). The initial phase would focus on robotic exploration of the Moon. It would begin with the launching of the *Lunar Geoscience Observer*, which will map the surface, perform geochemical studies, and search for water at the poles. Depending on the discoveries of the *Observer*, robotic landers and rovers may be sent to the surface to obtain more

"This initiative represents a sustained commitment to learn to live and work in space."

Apollo 15 lunar module

information. Mapping and remote sensing would characterize the lunar surface and identify appropriate sites for the outpost. . . .

Phase II: Return to the Moon (2000-2005). Phase II begins with the return of astronauts to the lunar surface. The initiative proposes that a crew be transported from the Space Station to lunar orbit in a module propelled by a lunar transfer vehicle. The crew and equipment would land in vehicles derived from the transfer vehicle. Crew members would stay on the surface for one or two weeks, setting up scientific instruments, a lunar oxygen pilot plant, and the modules and equipment necessary to begin building a habitable outpost. The crew would return to the orbiting transfer vehicle for transportation back to the Space Station.

Over the first few flights, the early outpost would grow to include a habitation area, a research facility, a rover, some small machinery to move lunar soil, and a pilot plant to demonstrate the extraction of lunar oxygen. By 2001, a crew could stay the entire lunar night (14 Earth days), and by 2005 the outpost would support five people for several weeks at a time.

Phase III: At Home on the Moon (2005-2010). Phase III evolves directly from Phase II, as scientific and technological capabilities allow the outpost to expand to a permanently occupied base. The base would have closed-loop life-support systems and an operational lunar oxygen plant, and would be involved in frontline scientific research and technology development. The program also requires the mobilization of disciplines not previously required in the space program: surface construction and transportation, mining, and materials processing.

By 2010, up to 30 people would be productively living and working on the lunar surface for months at a time. Lunar oxygen will be available for use at the outpost and possibly for propellant for further exploration.

This initiative envisions frequent trips to the Moon after the year 2000 — trips that would require a significant investment in technology and in transportation and orbital facilities in the early 1990s. . . .

The transportation system must be capable of regularly transporting the elements of the lunar outpost, the fuel for the voyage, and the lunar crew to low-Earth orbit. This requires a heavy-lift launch vehicle and a healthy Space Shuttle fleet. The transfer of both cargo and crew from the Space Station to lunar orbit requires the development of a reusable space transfer vehicle. This and a heavy-lift launch vehicle will be the workhorses of the Lunar initiative.

The Space Station is an essential part of this initiative. As the lunar outpost evolves, the Space Station would become its operational hub in low-Earth orbit. Supplies, equipment, and propellants would be marshalled at the Station for transit to the Moon. It is therefore required that the Space Station evolve to include spaceport facilities.

In the 1990s, the Phase 1 Space Station would be used as a technology and systems test bed for developing closed-loop life-support systems, automation and robotics, and the expert systems required for the lunar outpost. The outpost would, in fact, rely on the Space Station for many of its systems and subsystems, including lunar habitation modules which would be derivatives of the Space Station habitation/laboratory modules. . . .

The establishment of a lunar outpost would be a significant step outward from Earth — a step that combines adventure, science, technology, and perhaps the seeds of enterprise. Exploring and prospecting the Moon, learning to use lunar resources and work within lunar constraints, would provide the experience and expertise necessary for further human exploration of the solar system.

The Lunar initiative is a major undertaking. Like the Mars initiative, it requires a national commitment that spans decades. It, too, demands an early investment in advanced technology, Earth-to-orbit transportation, and a plan for Space Station evolution. . . .

However, this initiative is quite flexible. Its pace can be controlled, and more important, adapted to capability. It is possible to lay the foundation of the outpost in the year 2000, then build it gradually, to ease the burden on transportation and Space Station at the turn of the century.

The Lunar initiative is designed to be evolutionary not revolutionary. Relying on the Space Station for systems and subsystems, for operations experience, and for technology development and testing, it builds on and gradually extends existing capabilities. Many of the systems needed for reaching outward to Mars could be developed and proven in the course of work in the Earth-Moon region. It is not absolutely necessary to establish this stepping stone, but it certainly makes sense to gain experience, expertise, and confidence nearer Earth first, and then to set out for Mars.

HUMANS TO MARS

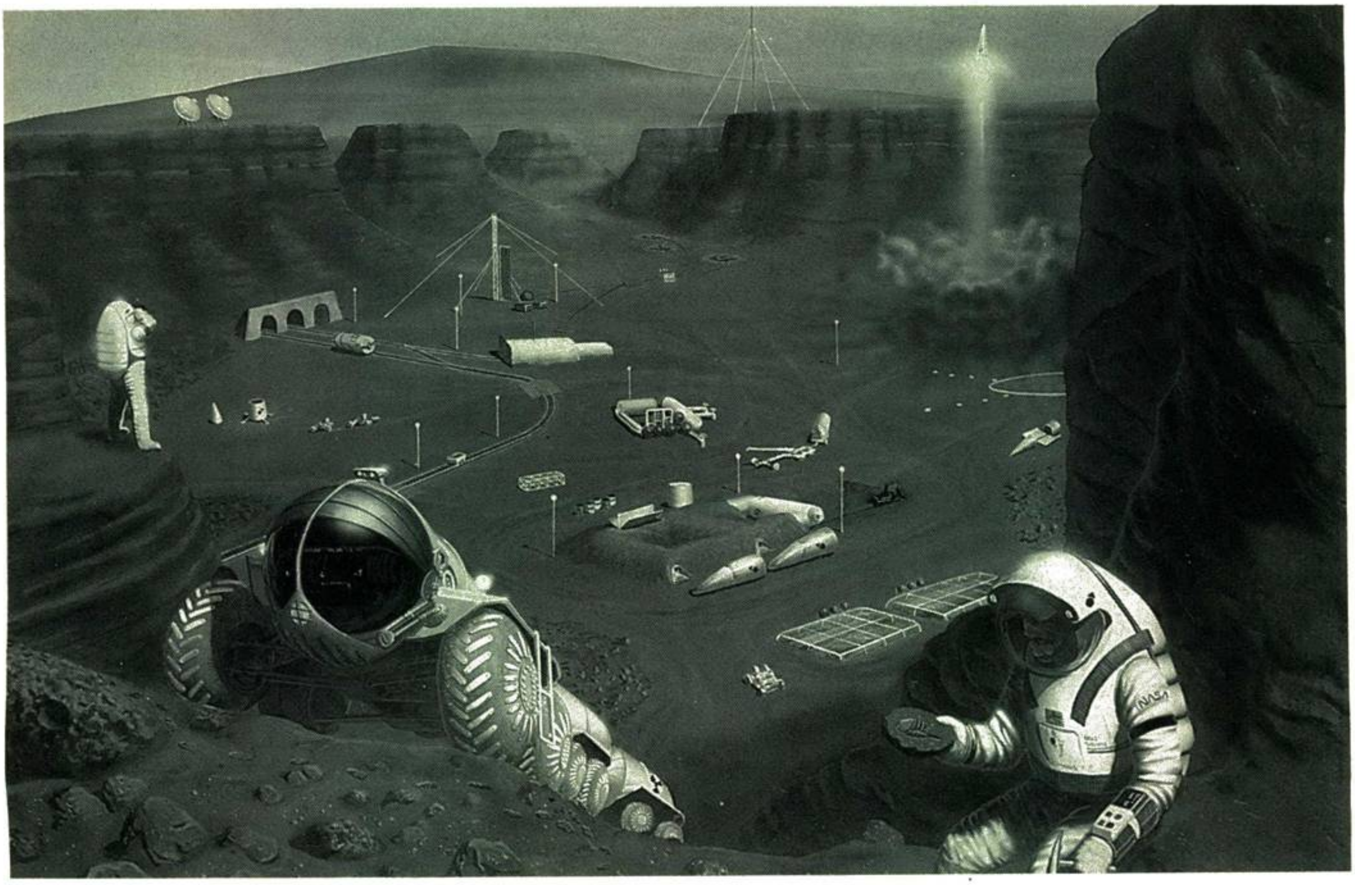
This bold initiative is committed to the human exploration, and eventual habitation, of Mars. Robotic exploration of the planet would be the first phase and would include the return of samples of Martian rocks and soil. Early in the 21st Century, Americans would land on the surface of Mars; within a decade of these first piloted landings, this initiative would advance human presence to an outpost on Mars. . . .

This leadership initiative declares America's intention to continue exploring Mars, and to do so not only with spacecraft and rovers, but also with humans. It would clearly rekindle the national pride and prestige enjoyed by the U.S. during the *Apollo* era. Humans to Mars would be a great national adventure; as such, it would require a concentrated massive national commitment — a commitment to a goal and its supporting science, technology, and infrastructure for many decades.

This initiative would:

1. Carry out comprehensive robotic exploration of Mars in the 1990s. The robotic missions would begin with the *Mars Observer*, include an additional *Observer* mission, and culminate in a pair of *Mars Rover/Sample Return* missions. These missions would perform geochemical characterization of the planet, and complete global mapping and support landing site selection and certification.

2. Establish an aggressive Space Station life sciences research program to validate the feasibility of long-duration spaceflight. This program would develop an understanding of the physiological effects of long-duration flights, of measures to counteract those effects, and of med-



Painting courtesy Pat Rawlings/Eagle Aerospace

"A successful Mars initiative would provide an exciting focus for creativity, motivation, and pride of the American people."

Olympus Mons

ical techniques and equipment for use on such flights. An important result would be the determination of whether eventual Mars transport vehicles must provide artificial gravity.

3. Design, prepare for, and perform three fast piloted round-trip missions to Mars. These flights would enable the commitment, by 2010, to an outpost on Mars.

The Mars missions described in this initiative are one-year, round-trip "sprints," with astronauts exploring the Martian surface for two weeks before returning to Earth. The chosen scenario significantly reduces the amount of mass which must be launched into low-Earth orbit, and by doing so brings a one-year round trip into the realm of feasibility. This is accomplished by splitting the mission into two separate parts — a cargo vehicle and a personnel transport — and judiciously choosing the launch date for each.

The Mars cargo vehicle minimizes its propellant requirements by taking a slow, low-energy trip to Mars. The vehicle would be assembled in low-Earth orbit and launched for Mars well ahead of the personnel transport, and would carry everything to be delivered to the surface of Mars plus the fuel required for the crew's trip back to Earth.

The personnel transport would be assembled and fueled in low-Earth orbit, and would leave for Mars only after the cargo vehicle had arrived in Mars orbit. It would carry a crew of six astronauts, crew support equipment, and propellant for the outbound portion of the trip. Once in Mars orbit, it would rendezvous with the cargo vehicle, refuel, and prepare for descent to the surface. The landing party would spend 10 to 20 days on the Martian surface, and then re-rendezvous with the personnel transport for the trip back to Earth orbit. . . .

A significant, long-term commitment to developing several critical technologies and to establishing the substantial transportation capabilities and orbital facilities is essential to the success of the Mars initiative. . . . Even with separate cargo and personnel vehicles, and technological advances such as aerobraking, each of these sprint missions requires that approximately 2.5 million pounds be lifted to low-Earth orbit. (In comparison, the Phase 1 Space Station is projected to weigh approximately 0.5 million pounds.) It is clear that a robust, efficient transportation system, including a heavy-lift launch vehicle, is required. . . .

The Phase 1 Space Station is a crucial part of this initiative. In the 1990s, it must support the critical life sciences research and medical technique development. It will also be the technology test bed for life-support systems, automation and robotics, and expert systems.

Furthermore, we must develop facilities in low-Earth orbit to store large quantities of propellant, and to assemble large vehicles. The Space Station would have to evolve in a way that would meet these needs. . . .

A successful Mars initiative would recapture the high ground of world space leadership and would provide an exciting focus for creativity, motivation, and pride of the American people. . . .

Any expedition to Mars is a huge undertaking, which requires a commitment of resources which must be sustained over decades. This task group has examined only one possible scenario for a Mars initiative — a scenario designed to land humans on Mars by 2005. This timescale requires an early and significant investment in technology; it also demands a heavy-lift launch vehicle, a larger Shuttle fleet, and a transportation depot at the Space Station near the turn of the century. This would require an immediate commitment of resources and an approximate tripling of NASA's budget during the mid-1990s. . . .

One alternative is to retain the scenario developed here, but to proceed at a more deliberate (but still aggressive) pace, and allow the first human landing to occur in 2010. This spreads the investment over a longer period, and though it also delays the significant milestones and extends the length of commitment, it greatly reduces the urgency for Space Station evolution and growth, and consequently for transportation capabilities as well.

We must pursue a more deliberate program; this implies that we should avoid a "race to Mars." There is the very real danger that if the U.S. announces a human Mars initiative at this time, it could escalate into another space race. Whether such a race is real or perceived, there would be constant pressure to set a timetable, to accelerate it if possible, and to avoid falling behind. Schedule pressures, as the Rogers Commission noted, can have a very real, adverse effect. . . .

Settling Mars should be our eventual goal, but it should not be our next goal. . . . We should adopt a strategy of natural progression which leads, step by step, in an orderly, unhurried way, inexorably toward Mars.

CREATING THE FUTURE

The future is happening now for NASA scientists and engineers who are at work turning the four Ride Report initiatives into reality.

by Stephen Cole and Kristine R. Majdacic

The Ride Report
NASA

Sometime in the future the United States may send astronauts to live and work on the Moon. It may undertake a broad program to better understand our solar system. It may even embark on a manned journey to Mars.

But these ambitious national plans exist currently as visions in the process of materializing. Today they are experiments to conduct, decade-old plans to revise, opposing strategies to reconcile, instruments to design, and spacecraft to build. The vision of America's future achievements in space presented in the Ride Report are ideas still in the process of development. "This is not a final report," Ride emphasized. "Rather, it is a status report describing the work accomplished to date, and how this work will continue."

The four Ride Report initiatives are currently at vastly different stages of development. Some projects are only preliminary ideas gathered together for study. Others are advanced mission designs only a year or two away from construction. But across all the areas presented in the report, the future is, even in the absence of a declared national space goal, being worked on now.

The two unmanned initiatives are farthest along within NASA. Specific elements of both Mission to Planet Earth and Exploration of the Solar System had been well defined by NASA management, and the Ride Report drew directly from those studies. These initiatives are at one of four stages of development: identifying all possible approaches to the mission, selecting a few approaches to evaluate in depth, designing a chosen option, and testing and constructing the mission hardware.

The two manned missions are not this far along. The Outpost on the Moon and the Humans to Mars initiatives "did not have clearly delineated strategies available," said *Ride*, "and no specific organization within NASA was dedicated to their advocacy." Recently, however, NASA has begun to pull together its manned mission studies — some of which are over a decade old — and has created a top-level office to develop these ideas to the level of the Earth and solar system programs.

Human Travel to Mars

The moribund manned mission scenarios that are now being revived and that may lead, according to the Ride Report's timetable, to a Moon landing in the year 2000 and a Mars journey in 2005, crystallized during the *Apollo* era. In the late 1960s NASA's Marshall Space Flight Center in Huntsville, Alabama, under the direction of rocket pioneer Wernher von Braun, pursued manned Mars studies. Although lunar base and manned Mars missions were seriously considered as part of NASA's post-*Apollo* program, these plans were subsequently shelved in favor of space shuttle and Space Station development.

This situation has changed in just the last two years. In November 1985 NASA's Johnson Space Center in Houston initiated a joint study with Los Alamos National Laboratories to update the previous manned Mars studies. Since then Marshall Space Flight Center has continued to take a fresh look at manned Mars concepts.

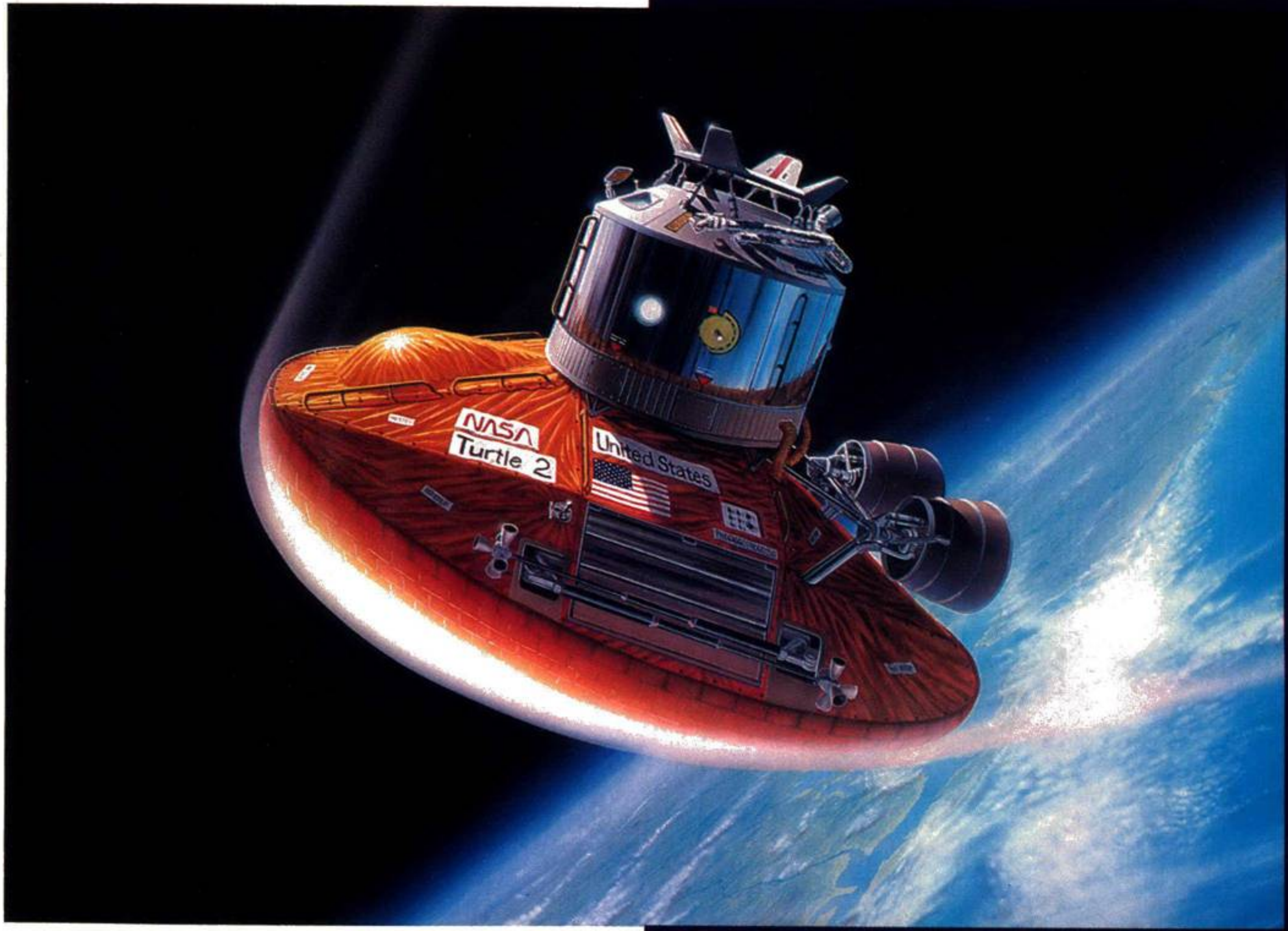
"We have been taking another look at defining the old mission profiles," said Bill Snoddy, deputy director of the program development office that performs early conceptual work on a variety of future projects at Marshall. "We're looking at all the possible pros and cons. For example, what role would the two Martian moons play in a mission to Mars? Just what would assembling the craft at the Space Station involve?"

Manned Mars missions have also been studied — and are now being revived — at other NASA centers as well. The new Office of Exploration at NASA Headquarters in Washington, D.C., was established last August to coordinate and advance these studies as well as nascent lunar base plans. (See related story on page 32.)

"Rather than all of us running off in ten different directions with our Mars studies, the Office of Exploration will be sort of a traffic cop for all this activity in the future," said Snoddy. "No one center can handle all these issues. Now that we are beginning to get serious about Mars, we need to proceed in an orderly way."

At this stage, fundamental components of a manned Mars mission are still being debated. For example, there is at this point no consensus that the "split mission" scenario presented in the Ride Report is the best way to go to Mars. This scenario proposes sending the mission's cargo ahead of the manned craft to reduce astronauts' travel time.

"That approach does minimize the worries associated with a long-duration manned flight," according to Snoddy. "But there are penalties you have to pay when you trade cargo weight for speed. This could involve sacrificing scientific equipment or the size of the crew's



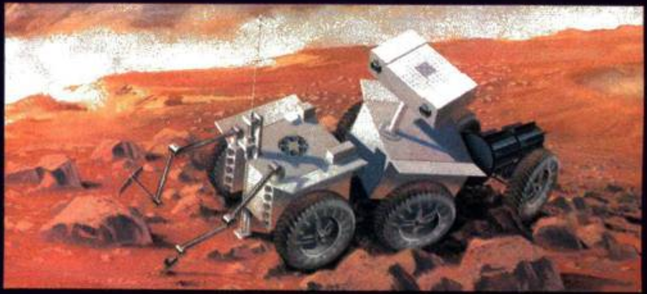
living area. Would we want to trade more payload for one less month of travel time?"

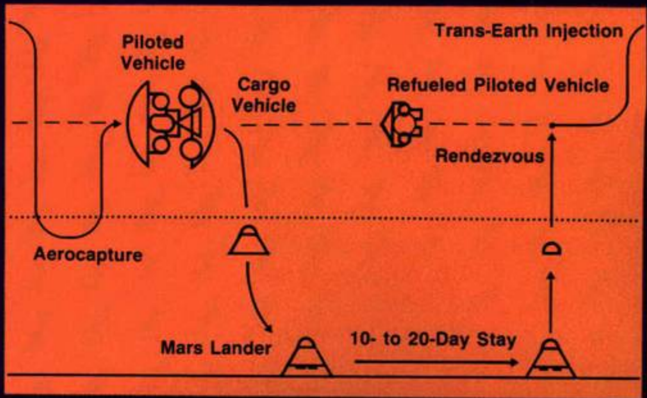
But problems remain with the single-craft approach, which could require up to a three-year round trip. "Can you rely on a vehicle that has to survive and take care of itself autonomously for that length of time?" asked Barney Roberts, who has been working on manned missions at Johnson Space Center's advanced programs office. "With one-way communication taking thirty minutes, how well could you respond to problems that might come up?"

While preliminary work on defining possible mission scenarios is under way, advanced research will soon begin on the technological tools critical to both lunar and Mars manned missions. Working with experts on both missions, NASA's space technology office has put together a package of research projects to develop various technologies for missions beyond Earth orbit.

The package — Project Pathfinder — includes research in robotics, advanced propulsion systems, and extraterrestrial resource development. "All the initial transportation technologies you need for Mars are in Pathfinder," said Roberts. The project, which received strong support in the Ride Report, is expected to go before Congress for funding in 1988.

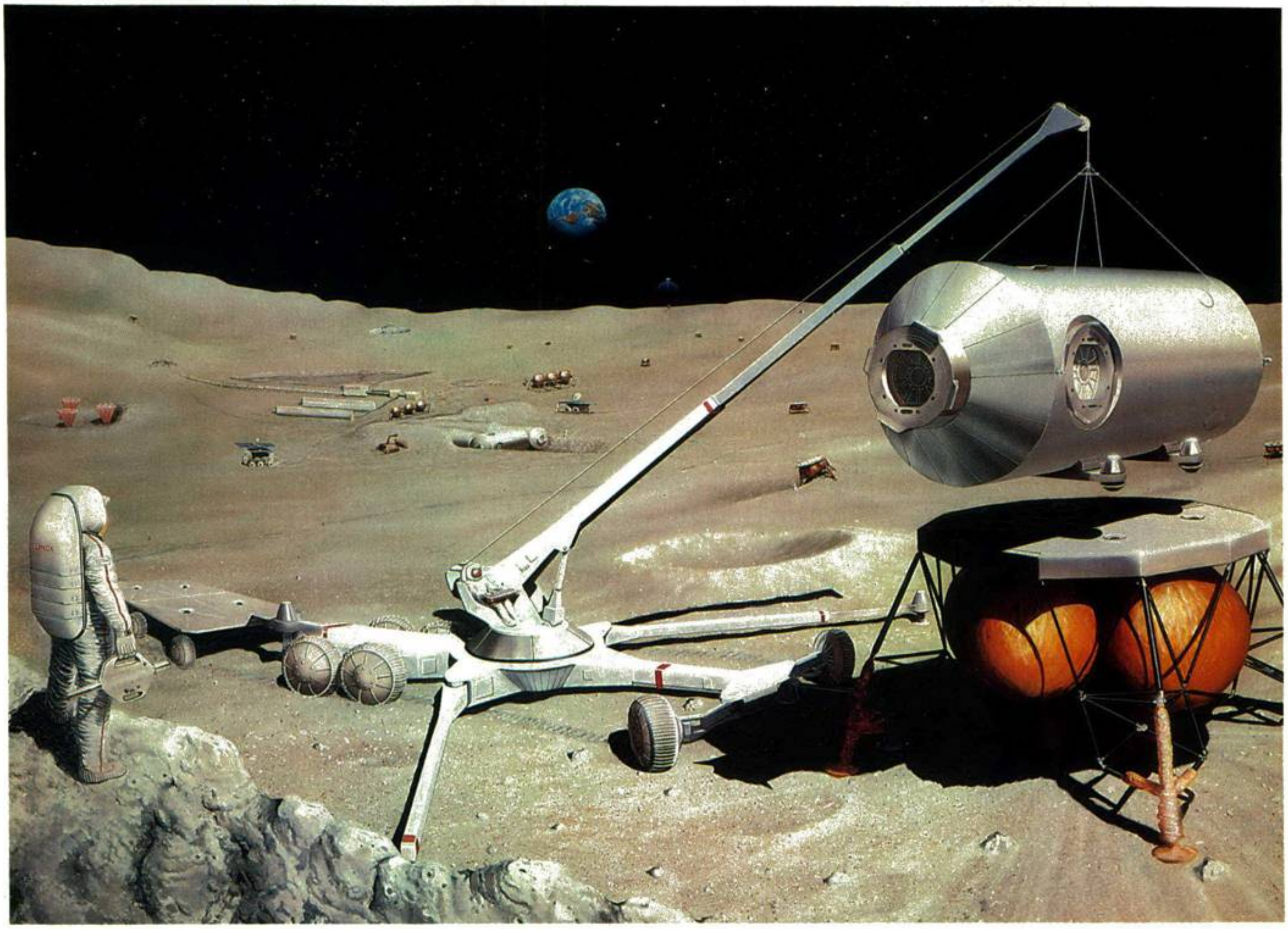
One of the Pathfinder projects would develop aerobraking technology. "Aerobraking was what we did originally with the Apollo capsules. We used the atmosphere to slow them down," Snoddy said. "We want to be able to slow down in a very controlled way so we end up in a particular orbit." Current Mars scenarios call for rendezvous with the Space Station upon return to Earth.





Top of page: Getting to Mars efficiently will require aerobraking technology, which uses a planet's atmosphere to slow a spacecraft down.

Above: The first stage of a return to Mars is gathering Martian samples with a mobile rover. A later manned mission could send cargo and astronauts in separate spacecraft. NASA illustrations.



Using the Moon's resources for construction, propellant, and life-support systems is a key component of lunar base planning. A habitation module is lowered into place at the site of a lunar mining facility. NASA illustration.

"There are two ways to go about stopping a spacecraft when it gets to a planet with an atmosphere. One way is to have propellant on board to use to slow you down. But you hate to have to haul propellant all the way to Mars and back to slow you down when you get back to Earth," Snoddy said.

The alternative is to use an aerobraking shield that will achieve the orbit without using all that fuel. "We think we can make these things much lighter than the propellant," said Snoddy. To develop this technology, Pathfinder contains an experiment — the Aeroassist Flight Experiment — that will test aerobraking technologies from the space shuttle.

Living on the Moon

Like Mars mission scenarios, the idea of permanently returning to the Moon has had a long history at NASA. Although official lunar base studies ended in 1972, an informal network of people within and outside NASA has been keeping these ideas alive and evolving since 1984. It was only in 1987 that lunar base work regained official status within NASA.

"In 1984 there was no organizational responsibility within NASA for lunar base work," said Wendell Mendell of Johnson Space Center. "Several people here at Johnson worked informally as an advocacy group to lobby for the project. A lot of the work has been done outside NASA by people at universities and corporations."

At a lunar base symposium hosted by NASA in October 1984, over eighty papers were presented on diverse aspects of lunar base development. "There is an enormous network of interested people," said Mendell, "who have put in their own time to develop their ideas up to a certain level. But at some point you have to stop."

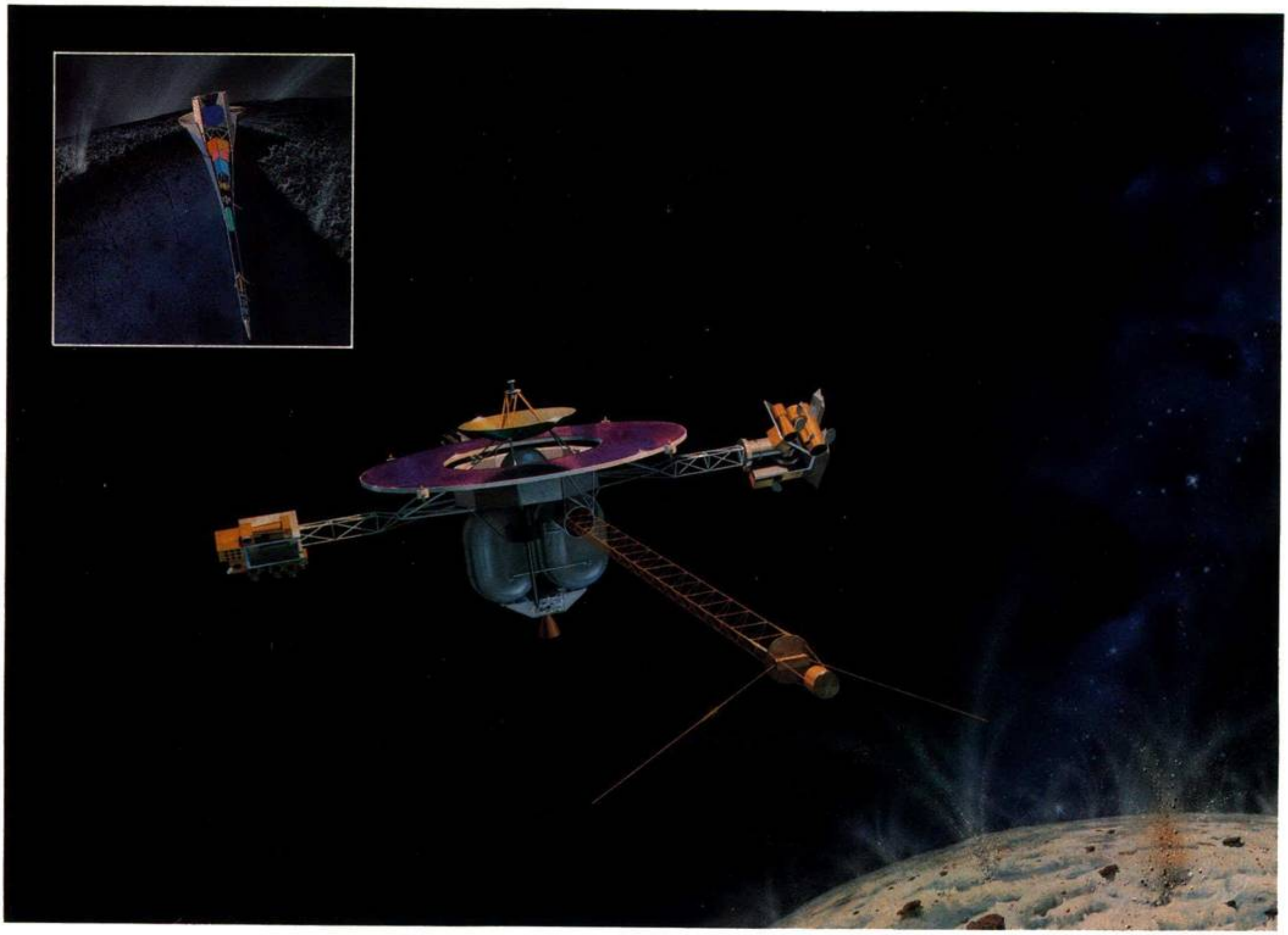
A second symposium, set for April 1988, has already generated over two hundred paper submissions. "There is real enthusiasm now, and there are a lot of new faces," said Mendell. "We've reached a new plateau."

The next step in developing lunar base concepts was taken in mid-1987 when Johnson awarded several study contracts. "The lunar base system study will focus the odds and ends of this previous work into a base-line scenario of what NASA should do," said Mendell.

"We've been dabbling around in details so far," said Barney Roberts, whose advanced planning office at Johnson will head up this study. "Now we will move to the next level of detail and develop strategies."

This stage requires collecting all the individual ideas that would make up a lunar base and studying them as a system. "A major system, like the Space Station, is a collection of elements that have a physical relationship to one another," said Roberts. "The lunar base is, like the Space Station, a large collection of individual systems. The problem is that this collection of systems is now held together by more abstract functional relationships between each of the systems."

The Johnson contract work will construct a computer model that Roberts will use to study the complex inter-



The *Comet Rendezvous Asteroid Flyby* mission will orbit Comet Tempel 2 for three years at close range. Inset: Cutaway drawing of the four-foot-long penetrator embedded in the comet to measure the composition of the nucleus. NASA illustrations.

relationships of a lunar base. All the components of a lunar base — power requirements, science programs, life-support systems, lunar resources mining — will be converted into a database. "This computer model will search for each system's functional relationship with the other systems," said Roberts. "As I give it upper level input — say, a certain number of people at the base — it will tell me now much oxygen requirements or power production goes up."

When the computer model is completed in mid-1989, it will be used to evaluate different scenarios like the one outlined in the Ride Report. "We plan to run six scenarios through the model, measure them with respect to one another, and then spend a year or so narrowing them down to a single scenario." The computer model will also include data on possible manned Mars missions so the two manned initiatives can be studied together to see how they affect each other.

A Three-Part Solar System Program

Like the Mars and lunar base initiatives, the missions presented in the Exploration of the Solar System initiative are not new proposals. But unlike the manned missions, the three solar system missions were officially recommended several years ago in a two-part report by NASA's Solar System Executive Committee that defined the scientific objectives and strategy for a balanced program of solar system exploration made up of basic research missions and more technically challenging missions.

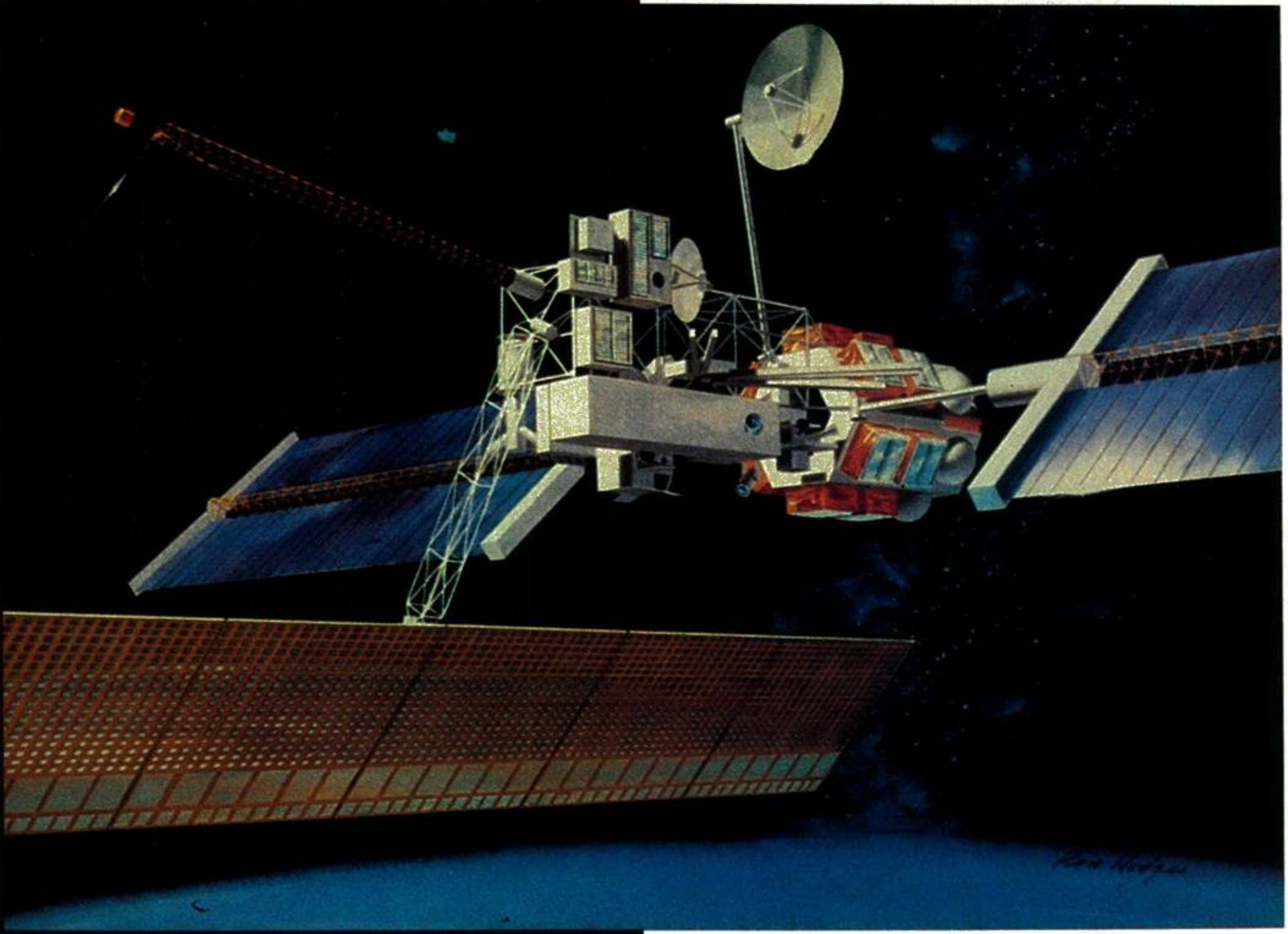
The current status of the three missions ranges from the *Mars Rover/Sample Return* mission, for which scenarios are currently being defined; to *Cassini*, for which the preliminary mission study is completed; to the *Comet Rendezvous Asteroid Flyby* mission (*CRAF*), which may receive funding in late 1988 to begin construction.

Task groups at the Jet Propulsion Laboratory (JPL) in Pasadena, California, and Johnson Space Center have teamed up to begin studying scenarios for the *Mars Rover/Sample Return*, the mission at the earliest stage of development. JPL is working on vehicles to traverse the Martian surface and collect samples as well as orbital vehicles to support the surface operations; Johnson is working on the vehicles that will get the mission to Mars orbit, down to the surface, and back to Earth.

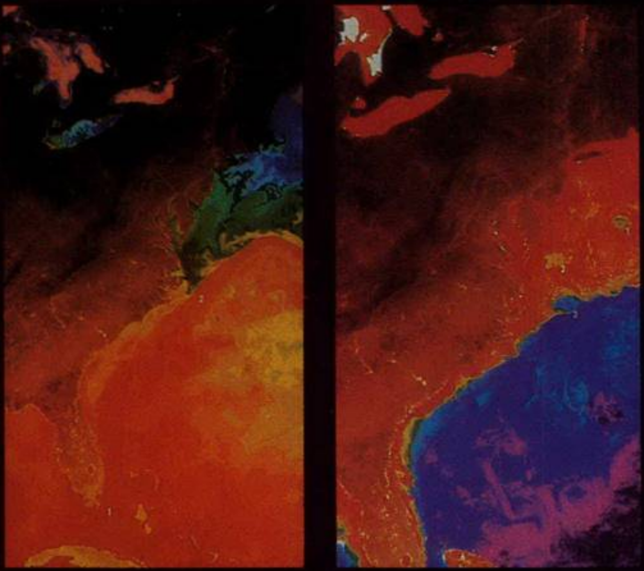
At this stage the mission is in the "realm of possibilities," according to Mark Craig, chief of the lunar and Mars exploration office at Johnson. "We're looking at as many ideas and approaches as we can to establish a feasible concept."

The task groups are currently evaluating possible scenarios for the mission. "For example, we have not pinned down how the rover will move around yet," said Don Rea, *Mars Rover/Sample Return* project manager at JPL. "The rover will also need some ability to evaluate potential samples and will perform science on its own, for instance, looking for water through electromagnetic sounding," Rea said.

Based on the work done in-house by the task groups,



Top of page: Mission to Planet Earth will make global observations of the planet with multiple instruments on four satellite platforms in polar orbits. NASA illustration.



Above: Satellite observations of sea surface temperature (left) and ocean color (right) are used to correlate marine productivity and physical oceanography. NOAA/NASA photos.

contracts were awarded in October by JPL to study rover mobility and surface rendezvous aspects of the mission and by Johnson to study Mars aerocapture, entry, and landing. These contracts will further explore the various approaches to the mission being considered at this stage. "We're open to new ideas," said Craig. "We want to keep study options open in the early stages, so we don't overlook options having high leverage for the mission."

Unlike the earlier *Viking* landers, which could only collect samples from one location, the Mars rover will be capable of moving around on Mars. This creates a new set of problems for mission planners. "A most challenging aspect of the rover is its operation from Earth with the involvement of the scientific community," said Craig. "The rover's mobility compounds the problem of how to efficiently maximize the scientific opportunity. With the *Viking* landers the decision-making process was somewhat ponderous because the science team was concerned about maximizing the scientific return of each operation." Because the rover is like "an infinite number of *Viking* landings," that time problem will be vastly multiplied.

The contractors will return their results to the task groups in September. The next stage in the mission will be to converge the options from this study into a smaller set of options that merits further study.

For the *Cassini* mission, the joint NASA and European Space Agency (ESA) probe to Saturn and its moon Titan, the study of the mission design, the science objectives, and the space flight system for the U.S. half of the mission, the Saturn orbiter, is complete. But the project won't move from the conceptual to the design stage until

ESA completes its study of the Titan Probe. "We're about a year ahead of the Europeans," said John Beckman, *Cassini* study manager at JPL.

Cassini is actually somewhat farther along than the early design stage because it will be borrowing some elements of other missions that are already designed. *Cassini* will use gravity-assist techniques similar to those developed for the *Galileo* mission to Jupiter and the spacecraft already being developed for the *CRAF* mission, according to Beckman.

A joint NASA/ESA announcement of opportunity is being prepared for mid-1989 to request proposals from the scientific community for instruments to fly on the mission. "We'll mix and match the best instruments from both continents," Beckman said.

One focus of *Cassini* is to probe the prebiotic atmosphere of Titan and determine the nature of Titan's surface. Because Titan has such a dense atmosphere, scientists don't know what its surface is like — rough, smooth, or liquid. "We don't know how to land on all of those surfaces with one probe," Beckman said.

The current design would slow the probe down with a parachute, though the probe may not survive the landing. Using instruments that measure the probe's acceleration, scientists will be able to determine what the surface of Titan is like by how the probe lands. "Different landings have different characteristics," Beckman said. "Plus we'll get pictures of what the surface is like during the final descent, and we also hope to get data after the probe touches down."

While *Cassini* waits for the Europeans, *CRAF*, the most developed mission in this initiative, waits for funding. The mission has progressed through the detailed design stage, "though no flight hardware has been built yet," according to Ron Draper, *CRAF* project manager at JPL.

CRAF will conduct multiple investigations at Comet Tempel 2: mapping the comet's entire surface, collecting dust grains from the comet's tail, and probing the comet's composition with an instrument that will penetrate the nucleus. The penetrator is four feet long and will be hurled toward the comet at 90 miles per hour. "It has to penetrate ice as hard as basalt rock," Draper said.

A prototype of the penetrator is being tested to determine if it will be able to penetrate the comet's nucleus without going through it. The designer of the penetrator, William Boynton of the University of Arizona, performed the test at Sandia National Laboratory in Albuquerque, New Mexico, in September. The prototype successfully completed the "hard" test: penetrating solid ice even when dropped at an angle of 60 degrees.

Because scientists don't know exactly how dense the comet nucleus is, shooting the penetrator into very weak ice — the "soft" test — will determine whether or not the penetrator will go through the nucleus.

"We want two penetrators on board," Draper said. "But each penetrator weighs about 50 pounds, so there may be a trade-off of experiments in the future. Right now we'd like funding for two."

Long-Term Observations of Earth

Mission to Planet Earth, like the solar system initiative, draws on recommendations already formally presented to NASA management. But, while the solar system missions can be developed independently of one another, Mission to Planet Earth involves multiple, interrelated components developed by NASA, other federal

ASTRONOMY READER POLL

Deciding America's Future in Space

"It is not NASA's role to determine the overall strategy for the civilian space program; that must be a national decision."

— Sally K. Ride

The Ride Report presents several long-range goals the United States' space program can pursue in the future. To promote the debate on this important issue, ASTRONOMY wants to know what you think about America's space future. Please take a moment to fill out the Reader Poll on the back of this page and send it to:

ASTRONOMY Magazine
READER POLL
1027 North 7th Street
Milwaukee, WI 53233

Surveys received by February 1, 1988, will be tabulated and the results will be published in the May 1988 issue of ASTRONOMY.

ASTRONOMY READER POLL

1. What aspect of our space program would you like to see as the dominant focus for NASA in the future? Please rank the following choices (highest, 1; lowest, 4).

__ Manned space flight
__ Solar system exploration
__ Orbiting observatories
__ Advanced space flight vehicles
__ Other ____________

2. Are you worried about the Soviet Union's apparent lead over the United States in several areas of space, for example, space station development and exploratory missions to Mars?

__ Yes
__ Slightly concerned
__ No

3. Would you like to see the United States pursue manned expeditions to other bodies in the solar system?

__ Yes __ No

4. Would you support a national goal to establish a permanent manned base on the Moon?

__ Yes __ No

5. Would you support the manned exploration of Mars?

__ Yes __ No

6. If, because of limited funding, the United States could not pursue a balanced exploration of the solar system, which one area would you like to see further explored?

__ Inner solar system (Venus, Moon, Mars)
__ Outer solar system (Jupiter, Saturn, Uranus, Neptune)
__ Primitive bodies (comets, asteroids)

7. Comments. Please include your name and address if you would like to grant ASTRONOMY permission to publish your comments.

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agencies, and other national space agencies, each of which is at a different stage of development but which must eventually fit together to gather the most comprehensive observations of Earth's atmosphere, surface, oceans, and interior ever made.

The centerpiece of this initiative is the Earth Observing System (Eos), a data information system that includes a system of four polar platforms to gather global observations of Earth. The first polar platform is being built as part of the Phase 1 Space Station and has been funded. Final contracts are being negotiated to build the platform.

Polar platforms are a new class of satellite, much larger than current satellites. A full-size U.S. platform will be able to support a payload of 6,600 to 7,700 pounds. Unlike current satellites that have a limited lifetime, these platforms were designed to be serviced by Space Station crews and are expected to orbit Earth permanently.

Though the platform does not share hardware with the Space Station, the platform was included as part of the Space Station facility, so that it would be generic and support a variety of uses with a "richer suite of instruments," said Dixon Butler, Eos program study scientist. "If Eos had built the platform, it would have been useful only for Eos payloads."

NASA will also build the second Eos polar platform. In addition, the European Space Agency and Japan are each expected to provide a polar platform. Japan has included a platform in its long-range flight plan with a launch in 1998. It will be a half-size platform that will support a payload of 3,750 pounds. "There is currently some uncertainty about whether ESA will provide a half- or a full-size platform," Butler said.

NASA has just begun the detailed design of the platform's six standard research instruments. The specialized instruments to be carried on the platform, however, have not yet been selected. To draw in proposals for the specialized instruments to fly aboard the first polar platform, an announcement of opportunity this month will request proposals for scientific investigations in three areas: instrument investigations, interdisciplinary investigations (research with multiple instruments cutting across traditional Earth studies), and team members and leaders to operate NASA's six research facility instruments.

Aside from collecting global measurements of Earth, Eos includes a revolutionary information management system that will "draw together space observations so scientists who need to assimilate large amounts of data into analytic models can easily gather the data they need," according to Butler. This management system will also control the operation of the equipment in space and provide access to data collected by geostationary platforms and other specialized research satellites.

Eos will be completed, according to current plans, by the year 2000. But that timetable, like the timetables of the other Ride initiatives, is not something mission planners can control. An uncertain future is something that everyone working on these missions has to face in the absence of a national commitment to these projects.

Current work on these ambitious initiatives could reach the point where the projects either have to stop development, scale down their plans, or face cancellation. The work of the scientists and engineers will actively proceed on these missions, but will the American people, the president, and Congress actively provide the support to move these programs ahead? The difference between "will do" and "have done" rests on just such support.

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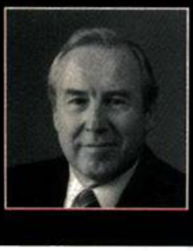

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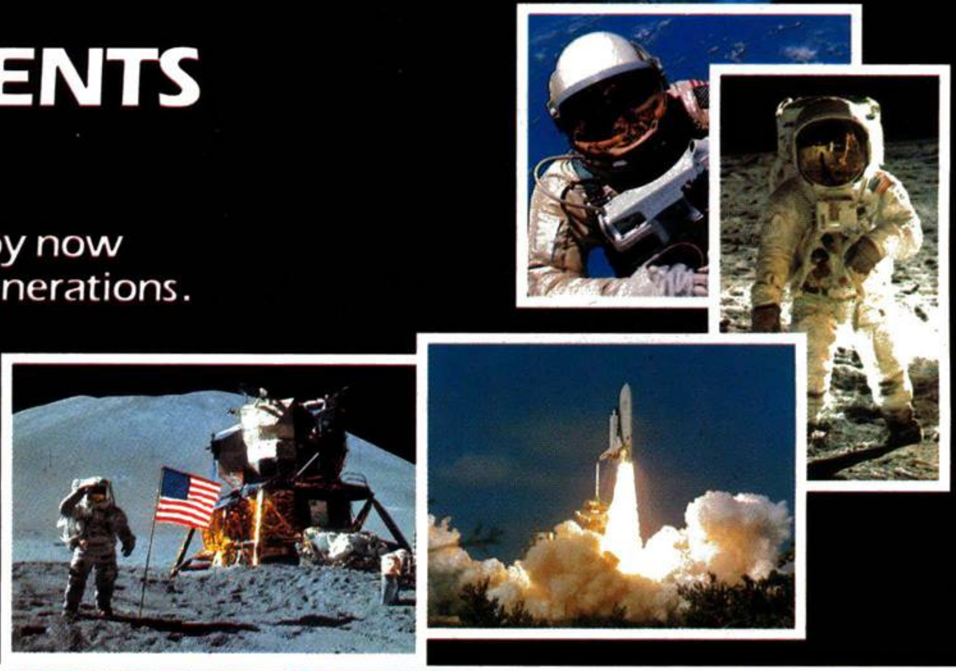

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Is the Milky Way an Interacting Galaxy?

by Gerrit L. Verschuur

Astronomers now believe a vast, warped halo of hydrogen clouds wraps around the Milky Way's disk like the tilted brim of a hat. Evidence shows fast-moving material streaming toward the Milky Way's satellite galaxies, the Magellanic Clouds. Have these two tiny galaxies interacted with the Milky Way and distorted its shape?

The Milky Way Galaxy is an interacting galaxy, according to radio astronomers. The disk of stars we live in is linked to the Magellanic Clouds, our Galaxy's satellites, by an enormous arc of neutral hydrogen called the Magellanic Stream. These startling facts have recently been established by piecing together many seemingly unrelated bits of evidence into a new picture of our Milky Way Galaxy. The discoveries that led up to this grand picture of the Milky Way's interaction date back over fifty years to create one of the best detective stories in modern astronomy.

The realization that ours is an interacting galaxy is only the latest result of an intensive effort to map the Milky Way. Since the 1930s, astronomers have tried to discover just how our Galaxy is built. Charting the Milky Way hasn't been easy, because we are inside it and our view of the Milky Way is obscured by cosmic dust. This dust creates a region called the "zone of avoidance," a band centered along the galactic plane that blocks visible light from objects beyond nearby objects in the Galaxy. Thus radio astronomers have become the Milky Way mappers because cosmic radio waves penetrate the dust and reveal the grand scheme of our Galaxy.

The Rise of Radio Astronomy

Radio astronomy began accidentally in 1932, when Karl Jansky at Bell Laboratories tried to find out why interference affected transatlantic radio telephones. Jansky accidentally discovered strange radio noise from space, and thus radio astronomy was born.

But most researchers weren't interested in pursuing radio astronomy. Among the few who were was amateur astronomer Grote Reber, who built a dish-shaped radio reflector in his backyard. Reber confirmed that the Milky Way was a source of radio waves, but observations of this radiation ultimately revealed little about the structure of the Galaxy.

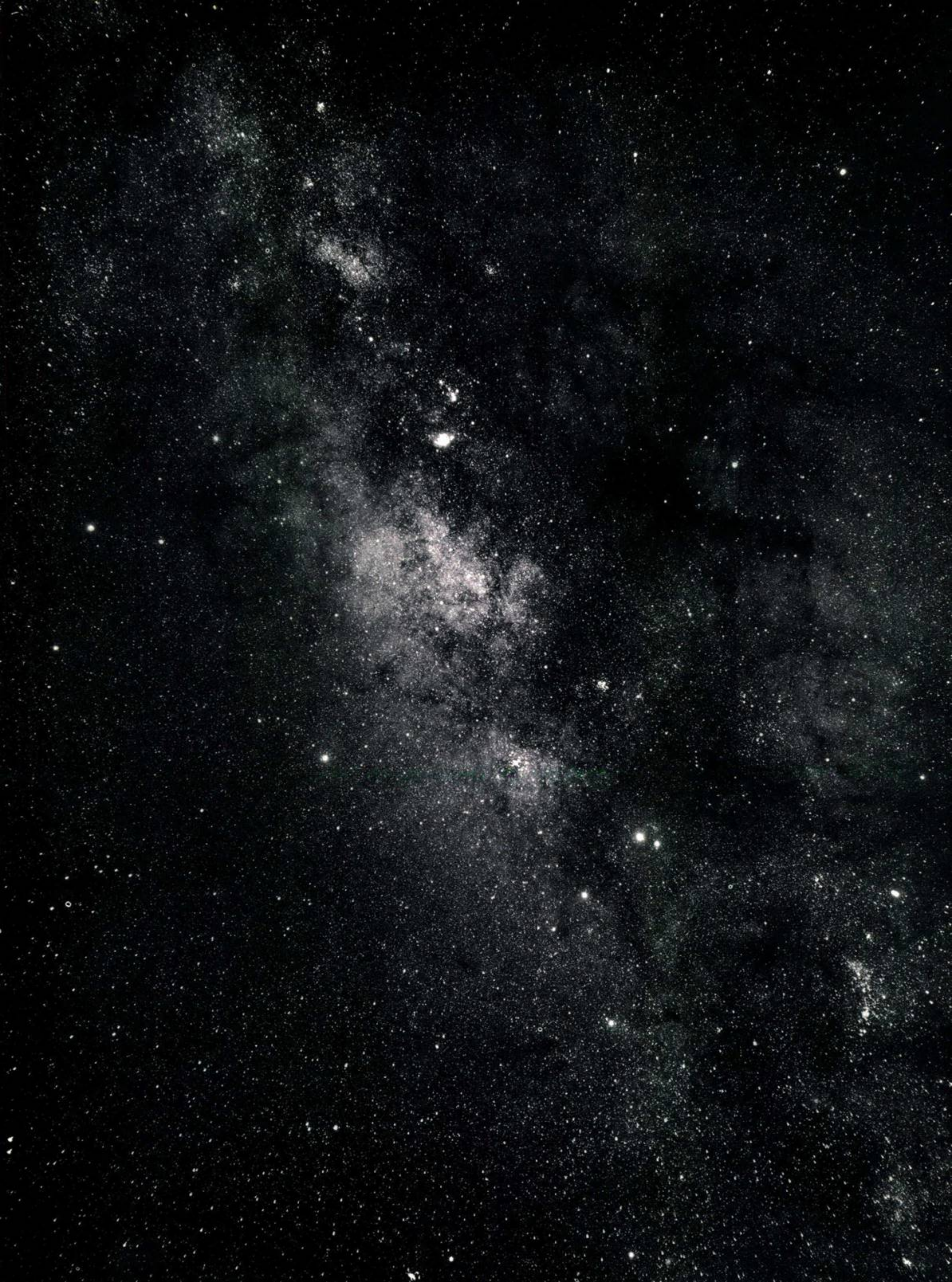
Then in 1944 a young astronomer in occupied Holland who was interested in radio astronomy wrote an unusually provocative paper. Henk van de Hulst authored an essay that suggested, among other things, that a spectral line might be produced by neutral hydrogen gas between the stars and, if so, should be observable. Interstellar neutral hydrogen (abbreviated HI) actually does emit a line with a wavelength of 21 centimeters and would prove in time to be the key to the structure of the Galaxy. But at that time no one knew this, and so the young field of radio astronomy limped along at a slow pace.

The existence of neutral hydrogen gas had previously been suspected, but neutral hydrogen was invisible to optical telescopes. Because of the speculative nature of van de Hulst's paper, few astronomers in the World War II era took this insightful article seriously. Ultimately, however, the ideas in van de Hults's paper "foreshadowed" a major branch of radio astronomy — the study of the distribution of neutral hydrogen gas throughout the Galaxy — but at the time van de Hulst's ideas were forgotten.

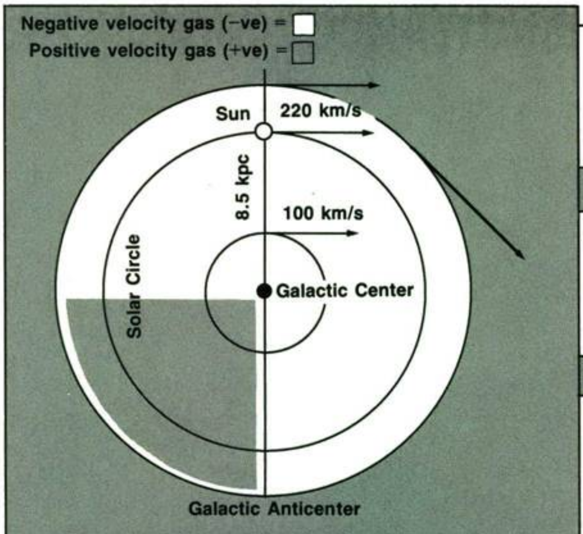
In 1951 a group of astronomers in Holland, the United States, and Australia made a great discovery: they found neutral hydrogen emits radio radiation at 1420.4 megahertz, which corresponds to a wavelength of 21.2 centimeters. This discovery allowed astronomers to begin the slow process of mapping the Milky Way by observing neutral hydrogen with radio telescopes.

Because their wavelengths are so much longer than the size of the dust particles, the long radio waves produced by neutral hydrogen pass unaffected by interstellar dust. Thus radio telescopes can easily "see" neutral hydrogen by observing at this specific wavelength. Moreover, because the wavelength of the line could be measured, astronomers could measure the velocity of the gas they detected and hence glean some information about the distance of the gas. By doing so, astronomers could not only peer beyond the veil of cosmic dust that had until the 1950s locked the secrets of the Galaxy away but also

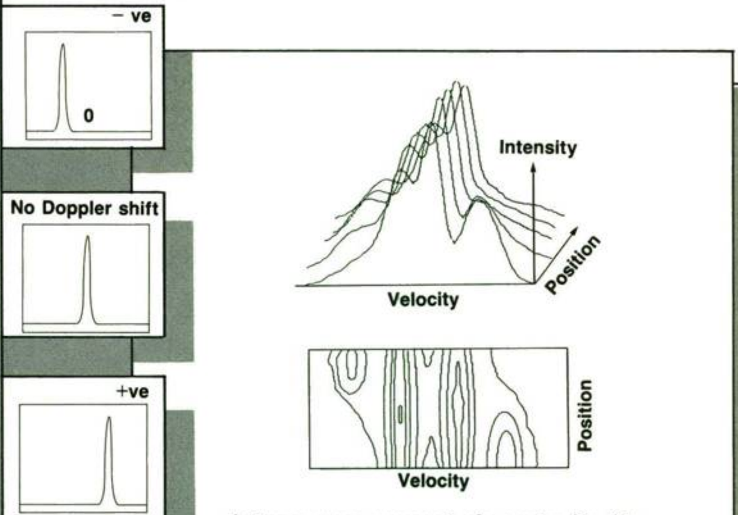
Courtesy Harvard College Observatory



Where Is the Warp?


Negative velocity gas (−ve) = ☐
Positive velocity gas (+ve) = ▨
Sun
220 km/s
8.5 kpc
100 km/s
Solar Circle
Galactic Center
Galactic Anticenter

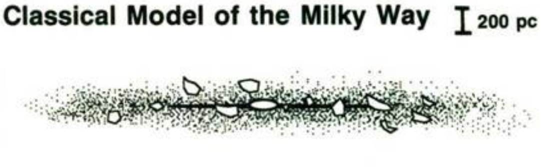
Gas viewed toward galactic center and anticenter shows no Doppler shift.



Astronomers use a set of spectra (top) to produce a contour map (bottom).

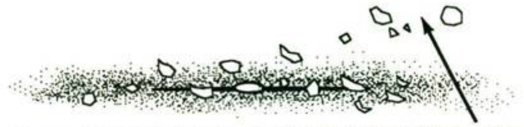
Where Are the Clouds?

Classical Model of the Milky Way



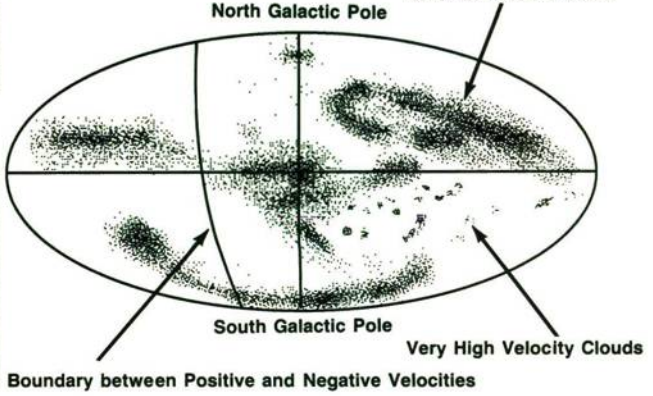
Hydrogen clouds moving randomly at low speeds

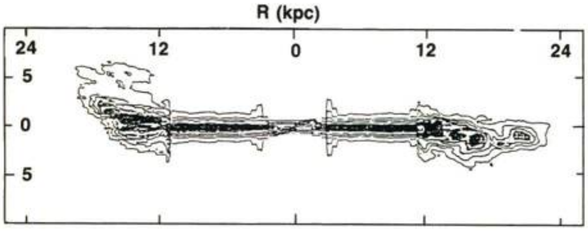
New Milky Way



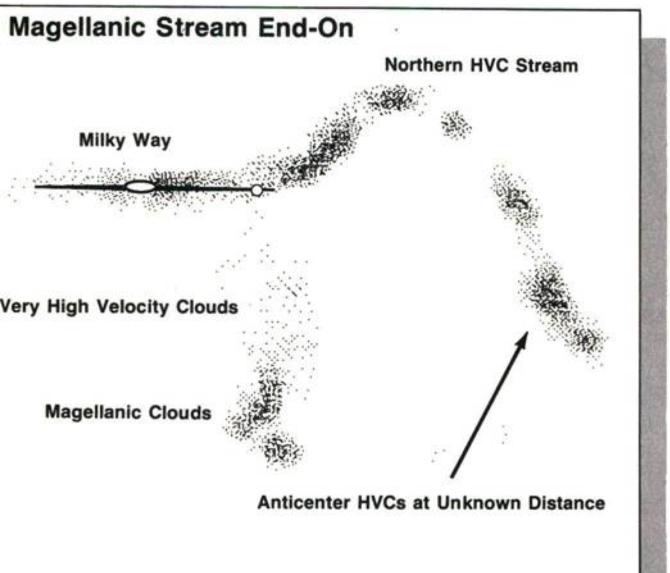
Large, distant hydrogen clouds moving at high speeds

The Sky at High Velocities


Northern HVC Stream?
North Galactic Pole
South Galactic Pole
Very High Velocity Clouds
Boundary between Positive and Negative Velocities



A schematic diagram of the Milky Way's HI layer, viewed edge-on, showing the distribution of neutral hydrogen in the outer Galaxy.



The realization that ours is an interacting galaxy is only the latest result of an intensive effort to map the Milky Way.

make an intelligent guess about the distribution of the gas.

Searching for Neutral Hydrogen

By 1954 the Dutch radio astronomers had taken the lead in developing images of the large-scale structure of the Galaxy, a lead they have not relinquished. The first neutral hydrogen maps suggested that spiral arms wind away from the galactic center, some 8.5 kiloparsecs away in the direction of Sagittarius. This was a surprise, because astronomers had previously thought the galactic center lay toward the constellation Norma.

In 1961 Jan H. Oort of Leiden Observatory conducted an experiment to test whether matter from intergalactic space was still falling into the Milky Way. To do this, Oort aimed his radio telescope away from the galactic plane and looked for blueshifted, infalling neutral hydrogen. Oort found plenty and noticed some of this neutral hydrogen had velocities much greater than he had expected. The clouds were moving toward us at 180 kilometers per second. But neutral gas close to the Sun normally shows Doppler shifts on the order of 10 to 20 kilometers per second. This limit, called the "speed of sound in space," is set by the speed at which particles can travel without creating a shock wave as they collide with other matter in the Galaxy. If gas travels faster than the speed of sound, collisions between particles would ionize the hydrogen and make it invisible at a wavelength of 21 centimeters.

Galactic rotation effects, on the other hand, can introduce Doppler shifts of as much as 150 kilometers per second for distant gas within the disk of the Milky Way. Astronomers see this effect along the plane of the Galaxy, where they're looking through a slice of the Galaxy that extends for thousands of parsecs. This shouldn't happen, Oort thought, in directions high above or below the plane of the Galaxy where only nearby gas is visible, because we're looking out through the thinnest dimension of the Galaxy. Yet gas with large velocities was discovered at just such a place — at galactic latitudes of 60°. How could this be?

If astronomers could measure the distances to these high-velocity clouds, the mystery would have been long since solved. But finding the distances to these clouds by direct measurement is a near-impossible task. There are no objects of calibrated distances — Cepheid variables — associated with these clouds. Instead astronomers only have clues.

If the Galaxy were flat, then you will only detect clouds above or below the galactic disk and they will be relatively close. But if the clouds are nearby, why do they have such high velocities?

Do their velocities mean they are well outside the Galaxy? If the clouds are extragalactic, or companion objects to the Milky Way, why are they scattered so widely across the sky? The mystery seemed insolvable.

Solving the Mystery of the Clouds

A few years after the high-velocity clouds were discovered, observations from several major observatories

> **The Magellanic Stream provides circumstantial evidence that the Milky Way's gravitational pull stripped gas from the Magellanic Clouds.**

revealed clouds of neutral hydrogen moving toward the Sun at 100 kilometers per second near the south galactic pole. Intuitively, it seemed as if the gas should be falling into the Galaxy. It was certainly moving toward the Galaxy at high speed. Then in 1974 Don Mathewson and his colleagues in Australia found that the clouds near the south galactic pole were only part of a long band of gas stretching across much of the southern sky. The Magellanic Stream, as it came to be known, originates at the Magellanic Clouds and extends 150° across the sky.

The Magellanic Stream appears to consist of a long string of gas clouds — most of which have velocities toward the Milky Way — leading to the Magellanic Clouds, and it appears to be a connection of material between the Milky Way and the Magellanic Clouds. If the stream is associated with clouds, and it certainly looks as if it is associated, then what was previously thought to be empty intergalactic space between the Milky Way and the Magellanic Clouds apparently contains a 100-kiloparsec-long streamer of neutral hydrogen. This stream of material measures as much as 5 to 10 kiloparsecs wide.

Early Views of the Milky Way

"So enormous is the number of stars, yet so completely incalculable are they, as to admit of their being joined with the sand upon the sea-shore, as a figure of speech denoting a numeration which we cannot define." So wrote Englishman Rev. Thomas Milner in 1858 in his book *The Gallery of Nature: A Pictorial and Descriptive Tour through Creation Illustrative of the Wonders of Astronomy, Physical Geography, and Geology*.

To assure his readers, lest they be overwhelmed by the size of the starry realm, Milner wrote that the Creator was "acquainted minutely with these multitudinous worlds, which immeasurably exceed our utmost estimates." Most noticeable in the heavens, he wrote, was "that luminous celestial highway which the Greeks called the Galaxy, and the Romans the *Via Lactea*, from its whiteness. By some of the Pagan philosophers the *Via Lactea* was regarded as an old disused path of the Sun, of which it had got tired, or from which it had been driven, and had left some faint impression of his glorious presense upon it."

Milner pointed out that the stellar composition of the Milky Way was suspected long before it was proved, and "its multitudinous host of stars remained a secret till Herschel turned his mighty instrument at Slough upon the silvery belt." Some glimmering of the scope of the Milky Way apparently began to dawn on Herschel when he reported observing no fewer than 258,000 stars in a region 10° by 2.5° across.

Milner also told of someone named Brydone who climbed Mount Etna and experienced a truly dark sky for the first time. "The sky was clear, and the immense vault of the heavens appeared in awful majesty and splendour. The whiteness of the Milky Way was like a pure flame that shot across the heavens, and with the naked eye we could observe clusters of stars that were invisible in the regions below. Surely, the situation alone is enough to inspire philosophy." Indeed, but today it has inspired far more than philosophy. It has inspired curiosity in the raiment of astronomy and has driven men and women to probe beyond belief, to construct new telescopes to discover what really is out there.

— Gerrit L. Verschuur

This vast streamer of gas suggests, in turn, that the Milky Way is interacting with its two small satellite galaxies. The Magellanic Stream provides strong circumstantial evidence that as the small galaxies hurtled past the Milky Way several hundred million years ago, the Galaxy's gravitational pull stripped gas from the Magellanic Clouds and created the Magellanic Stream.

Another finding followed Mathewson's in quick succession. Surveys aimed at finding still more high-velocity clouds revealed neutral hydrogen moving at speeds up to 465 kilometers per second below the galactic plane, beyond the end of the Magellanic Stream. R. J. Cohen of the Jodrell Bank radio observatory suggested that these very high-velocity clouds are patches of gas torn from the tip of the Magellanic Stream and are not attached to the Milky Way or the Magellanic Stream.

Clouds Lead to Warps

So where do the high-velocity clouds fit in? An interesting collateral discovery came from studying the northern high-velocity clouds, which extend above the plane of the Galaxy in the region between Cygnus and Cassiopeia. In the early 1970s Rodney Davies of Jodrell Bank and the author independently suggested that the Galaxy is strongly warped on its outskirts. So kinked is the outer envelope of neutral hydrogen, we suggested, that distant, spiral-like streamers of hydrogen rise far above the Milky Way on the outer edge of the Galaxy's disk and then turn down again.

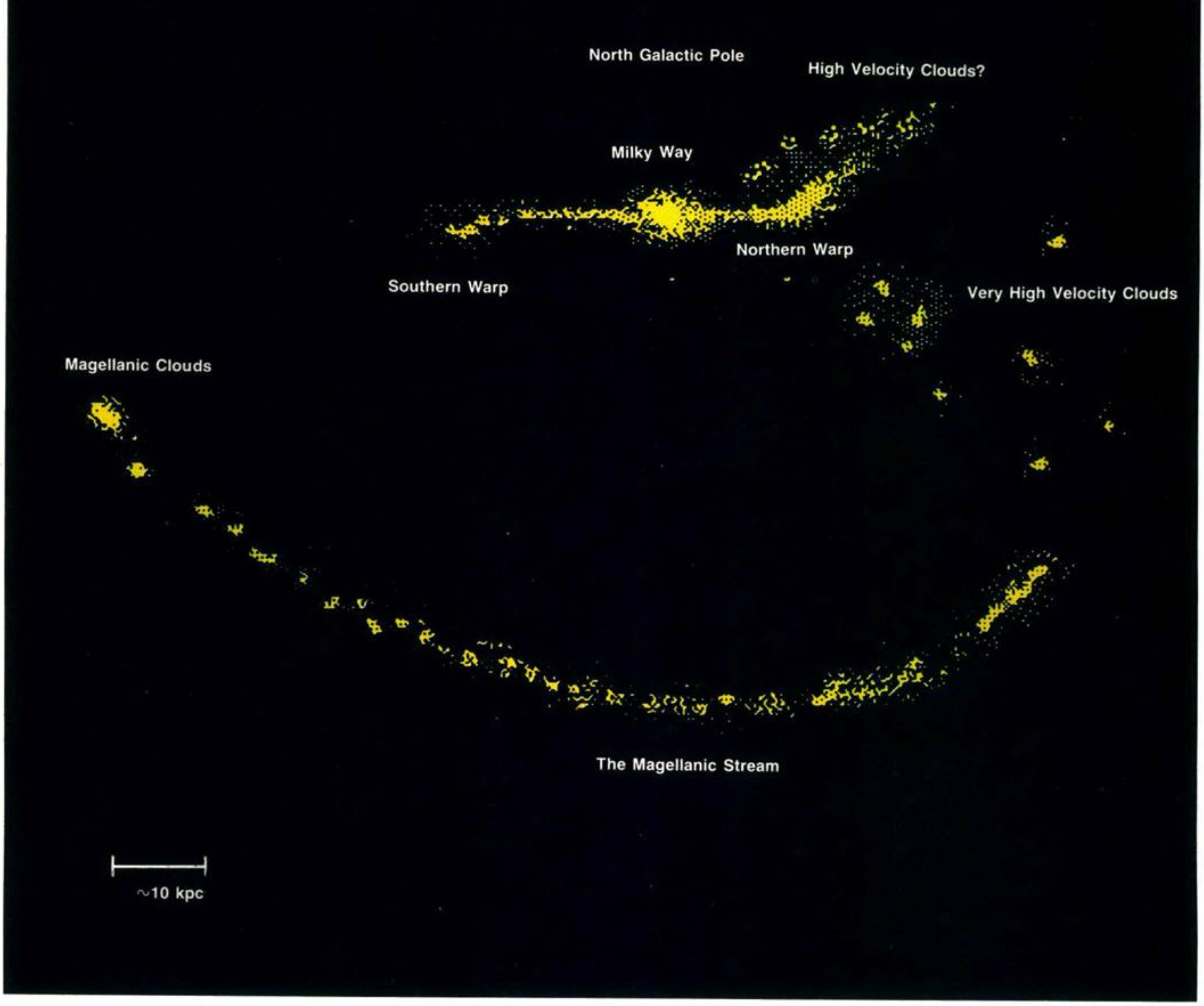
In the direction opposite the galactic center these streamers may extend far below the Galaxy's disk. There the gas is so distant it could hardly be considered part of an outer disk warp. Rather, the galactic anticenter gas clouds are an analog of the Magellanic Stream: they are a twisted stream of gas stretching away from the Galaxy on the other side of the sky. This great stream of material may begin as a spiral arm, warp out to great distances above the plane of the Galaxy, and then stretch into the depths of intergalactic space.

Because it was impossible to make a quantitative model of this phenomenon, the idea of a warp in the outer part of the Milky Way was not readily accepted by many astronomers. Above all, scientists want a quantitative explanation for a proposed model. This was difficult to produce for the warped disk model because, until distances for the clouds could be calculated, the idea lacked the necessary supporting numbers. Nevertheless the northern high-velocity clouds may represent a vast structure that flails from the edge of the Milky Way out into what is usually regarded as empty space.

Are There Stars in Those Clouds?

Interacting galaxies are relatively common in the universe. They often show one or more streamers of material reaching out and bridging intergalactic space, much as the Magellanic Stream appears to do. Some of the tails of other galaxies contain stars, but so far none has been observed in any of the high-velocity clouds around our Galaxy. Perhaps the stars aren't out there, or

Milky Way Interaction



perhaps they are too faint to observe. But the search for stars in high-velocity clouds continues, because if stars are found, we could estimate the distances to them based on their apparent magnitudes and the mystery of the locations of the high-velocity clouds would be solved.

Where Do the Clouds Take Us Now?

This year the model for high-velocity clouds proposed by Davies and the author received support from a new survey made by W. B. Burton at Leiden Observatory. Burton used the 140-foot radio telescope at the National Radio Astronomy Observatory in Green Bank, West Virginia. He combined his data with southern sky observations made by Frank H. Kerr and his collaborators at the University of Maryland to make a movie of galactic neutral hydrogen. The movie shows all of the neutral hydrogen in the sky between 20° and −20° galactic latitude. The film reveals distant spiral arms warping above the Milky Way's plane. The most distant gas becomes diffuse as it reaches high above the Galaxy's plane and high-velocity clouds are distributed consistently with the warped-disk model.

It is difficult to summarize the significance of the high-velocity clouds with great certainty, because the distances of these clouds are so poorly known. It appears that we live in an interacting galaxy linked in a vast cosmic dance with the orbiting Magellanic Clouds. Great streamers of hydrogen reach deep into space, well beyond the Milky Way's disk. But astronomers need to collect more data and propose hard physical models before we can be sure of the shape and history of our Galaxy.

Gerrit L. Verschuur is a freelance writer and researcher who lives in Greenbelt, Maryland. He is actively involved in radio astronomy and the author of The Invisible Universe Revealed, *published by Springer-Verlag. Verschuur's last article was "Something Passing in the Night," published in the December 1987 issue.*

ASTRONOMY
Forum

Planning for the Future: NASA's New Office of Exploration

If Sally Ride's recent report to NASA management on the future direction of the U.S. space program is any indication, America may have a much clearer sense in the post-*Challenger* era of where its space program is going than it did two years ago.

The report, commissioned by NASA administrator James Fletcher, takes a detailed, practical look at four major goals that NASA management developed in the wake of the *Challenger* disaster and the resulting Rogers Commission report. The intent of the report was to begin serious debate and study of these and other possible long-range goals. "The intent is not to choose one initiative and discard the other three," Ride said, "but rather to use the four candidate initiatives as a basis for discussion."

What course that debate takes in the public and legislative arenas is an open question. (We encourage you to make your views known through the Reader Poll "Deciding America's Future in Space" on page 23.) Ride clearly states, however, that making the decision is not NASA's job: "It is not NASA's role to determine the strategy for the civilian space program; that must be a national decision. But it is NASA's role to lead the debate, to propose technically feasible options, and to make thoughtful recommendations."

Even in the absence of declared long-range goals, NASA has made it clear that it is going ahead with its part of this process. If the Ride Report was the first step in establishing the context and leading the national debate, the newly created Office of Exploration represents NASA's commitment to keeping that debate alive and to actively developing the technical options that will one day be used to realize future goals.

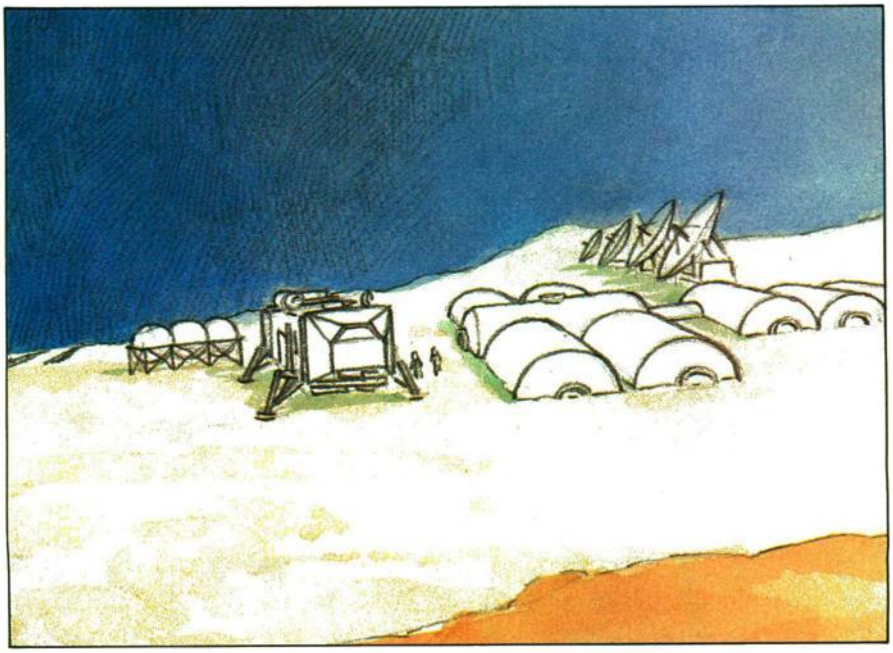
"There are considerable — even urgent — demands for a major initiative that would re-energize America's space program," said James Fletcher when he announced the formation of the new office last June. "This office is a step in responding to that demand." Ride was appointed acting director, although the office did not begin operation until August when John Aaron, special assistant to the director of Johnson Space Center, was named assistant administrator for exploration after Ride left the agency.

Aaron, who has managed Space Station work and studied Mars sample return concepts at Johnson, believes

"The formation of this office shows that NASA is dedicated to producing living, viable, long-range goals and plans."

— John Aaron
assistant administrator,
Office of Exploration

The Ride Report
NASA



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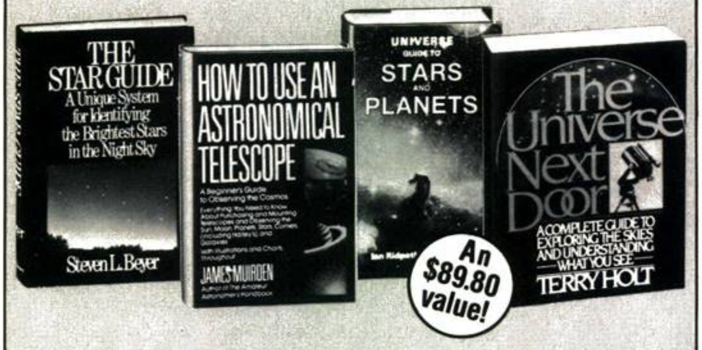
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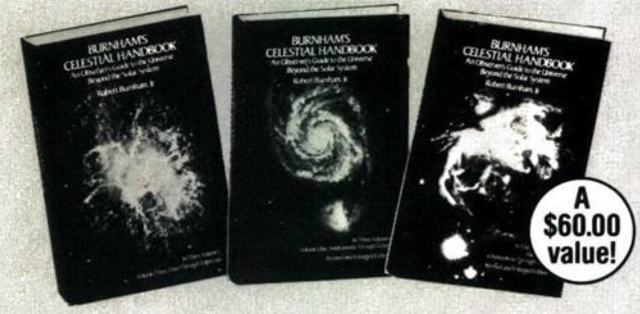
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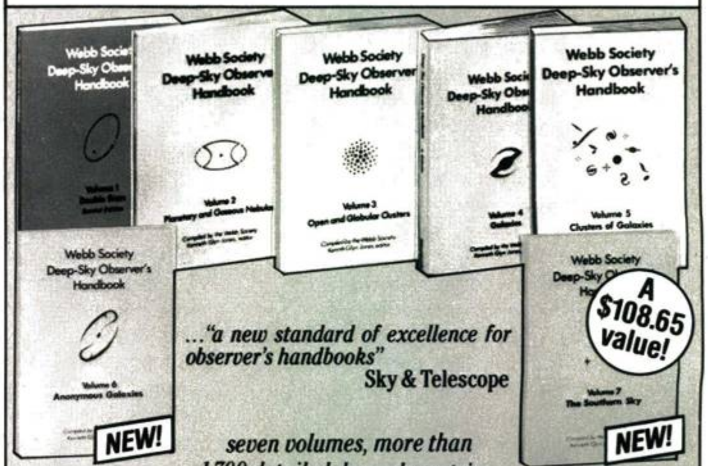
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Astronomy 1/88

the need for long-term NASA goals is, as Fletcher stated, urgent.

"The urgency comes in two flavors," said Aaron. "On the higher plane there is an urgency felt by Dr. Fletcher and others that we are at the point in the civil space program where we either take the next steps that maintain the sense of national leadership and space leadership this country has enjoyed or, by not taking those steps, we slowly lose that leadership position. I feel we are exactly at that pivotal point as a nation.

"The second sense of urgency has to do with current NASA programs. The one thing a lot of the recent external reviews of NASA, like the Rogers Commission report, state is that near-term programs — transportation, the Space Station — need to benefit from a long-range direction. It's very important to have the long-range direction in front of you so you can make intelligent, short-term, incremental investments in that goal."

The significance — and the success — of the Ride Report is that the report directly responded to that lack of direction. "Rightly or wrongly NASA has taken a lot of public criticism about a supposed lack of long-term direction," said Aaron. "What the Ride Report did was very succinctly focus on the near-term treatment of potential major initiatives and long-range goals.

"You could say that with respect to the space program the nation is marking time," observed Aaron. "I don't know who said it but it's a great thought: A great nation can't mark time and remain a great nation. I think great nations of the future, in order to be great, will have a major space component as part of their total approach."

As Ride points out repeatedly in her report, the first step in deciding on goals that will restore leadership is determining what kind of leadership you want. Alan Ladwig, special projects coordinator for the Office of Exploration and a member of the Ride Report study group, recalled how the idea of leadership arose as an issue unto itself.

"In the process of this study everyone kept slinging around the word 'leadership.' As we talked to different people, it became very clear that everyone had a different interpretation of what leadership was. It seemed as though we weren't all speaking the same language.

"We started to realize that being first is only one type of leadership, and it doesn't seem to be a very lasting type of leadership. After you decide what area you want to be a leader in, then you have to decide in what particular way you want to be a leader," said Ladwig. "A certain kind of leader will be first, another kind will build on somebody else's first, another kind will go for operational capability. This in my mind is what the Soviets are doing now: they are developing operational capability."

Aaron is confident NASA management is seriously moving in the direction of deliberate long-range planning. "With the Ride Report, NASA was making a conscious decision to elevate and focus that planning activity. Dr. Fletcher took a very active interest on a week-to-week basis in what was coming along," Aaron said.

"Creating an office of this size and at this level is not unusual," Aaron pointed out. "The formation of the office is significant, however, because it shows that the top level of NASA management is very dedicated to producing living, viable, long-range goals and plans for NASA. It also indicates that top management is very enthused about some of the potential missions we're talking about. I think that is a very positive step. And it has created some excitement and expectation both inside and outside NASA about what the agency might do next."

> ***"The Ride initiatives are not out of fiscal reality if there is a national sense that we want to do them."***

The Ride Report
NASA

Aaron's agenda, as established by Fletcher, is to "analyze and define missions proposed to achieve the goal of human expansion off the planet. The office will provide central coordination of technical planning studies that will involve the entire agency."

Before the establishment of the Office of Exploration, Aaron pointed out, "there wasn't the mechanism the agency needed to unify the strategies across NASA programs in the short term. One thing realized early in the Ride study effort was that these initiatives, particularly the two human-related ones, had such sweeping implications for the entire NASA organization that they needed to be put in an environment where the main-line organizations of NASA could work together to effect them. This office was created as a catalyst to work out these implications across the board."

The two manned initiatives will not be the only concerns of his office, however, said Aaron. "Dr. Fletcher has given me the charter to keep all four of the Ride initiatives on an equal footing and also to look for any other projects that would fall into the category of potential NASA goals and objectives. I feel I have a directive to make sure all four initiatives get equal analysis and study both inside and outside the agency."

According to Aaron, the planning effort of the Office of Exploration will be two-tiered: examining both long-term goals and their short-term implications. "The formation of the office did two things. One was to get the additional resources needed to go to the next phase of analysis on the Ride initiatives. And, by the way we do that analysis, we will also be able to provide long-range direction to the near-term development of existing programs — space science, transportation, the Space Station, technology, etc. All these ongoing programs have near-term increments and evolutions. By having the major organizations work their next stages into our long-range planning, we pick up the by-product that they can steer the next evolution of these programs in the short term."

The Office of Exploration has begun its planning effort by coordinating the other offices at NASA Headquarters and the NASA centers across the country that it will call upon for resources and expertise. "Each of the other NASA organizations had ongoing studies and ongoing planning resources to look at the various aspects of these initiatives. What I'm trying to do in 1988 is focus and define the initiatives and identify others. The plan is to continue the analysis with the efforts the other organizations have already planned and focus as well as synthesize those efforts. Even in 1989 and beyond, these other organizations will still support us in a major way."

The staff of Aaron's office, which is still being hired, will grow to about ten full-time members. The planning activity of the office will focus on three central areas: mission studies, technology and infrastructure, and science studies.

"The layout works like this," said Aaron. "The key to linking planning across the agency is developing potential ideas and requirements to some level and then fanning them out to the other organizations within NASA, so

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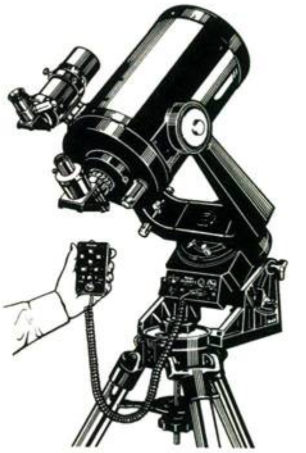
Jon Chase



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the organizations can study the ideas in detail and feed back the implications. Then the cycle is repeated.

"That's the mechanism I've chosen to run this engine. The mission studies office is the lead for developing the potential scenarios and the particular techniques of the initiatives. For example, it's one thing to say you want to go back to the Moon. It's another thing to say what timeline and what technique we use to get there. One scenario could say, let's go back with the emphasis on establishing a branch point for the exploration of Mars; another scenario might place the major emphasis on science or resource exploitation. The particular emphasis of a mission scenario has different implications for the Space Station, technology development, and so forth.

"Now, given that we have certain scenarios and certain techniques, the science studies area looks across all the science disciplines for what opportunities a particular scenario presents for scientific exploration. Then a science strategy is developed for that scenario.

"Likewise, the technology and infrastructure office will look at the scenario with an emphasis on the techniques used to achieve it. Because these scenarios will also have gradations of technology — one might say let's go to Mars with chemical propulsion, another might say let's use nuclear propulsion — these techniques will be fed back to the technology organization in NASA to help interpret what those scenarios and techniques mean to the technology needs of NASA so the technology programs can be put in place.

"The key thing that makes this engine work is having other offices like transportation and the Space Station take the scenario and technique blueprints and see what they mean to the near-term work at those offices. At some point you can put together all the implications summed up over the entire agency and begin doing some comparative analysis. You then run that analysis through multiple cycles and adjust your approach along the way."

Aaron is currently using 1992 as the deadline for completing this "mission analysis and system definition" process. At that point his work would be well enough developed so a commitment to a national goal could be made.

But there is nothing magic about the 1992 date. "In terms of our near-term planning, even if a major initiative were announced today, we would be doing pretty much what we are proposing to do now," said Aaron. "Fundamentally, for the next few years our preparations will concentrate on building up the technology base investments and funding the appropriate precursor missions."

Aaron believes the difference between long-range planning that produces little real progress and planning that steadily moves you toward a goal is developing the tools you'll need as you go. "It's important to begin fostering those 'long lead-time' items and get actual technology and research under way. There is a danger of doing studies that get too far out in the future and you end up just doing paper studies. The key thing that makes the advanced work really happen is incrementally building bridges toward your goal," said Aaron.

Project Pathfinder, a package of technology projects designed to develop advanced transportation and propulsion capabilities for future missions, represents just such an investment. "One of the things Pathfinder tries to do — because you can't go and do everything — is identify the common elements of all the possible things you want to do. Pathfinder is the subset of everything that's needed across all missions." NASA budget makers are recommending Pathfinder for funding in late 1988.

> ***"The great nations of the future, in order to be great, will have a major space component as part of their total approach."***

The Ride Report
NASA

The political problem with such an advanced technology project is that while its influence is great, its benefits are not very visible, especially in the short term. "Is anyone going to remember a president who gave you technology and infrastructure?" Alan Ladwig asked. "Well, probably not. But to me, that would be a leader, that's something that shows guts. It would be nice if this administration would step forward and say: We want to leave NASA a legacy to build on — Pathfinder. The longer you put off doing that technology, the farther off those goals are always going to be."

By this time next year Aaron hopes NASA will have been successful in selling Pathfinder to Congress so the project can get under way in late 1988. "I also hope we have a better understanding of the initiatives we have on the books today and have completed the search for additional ones. We're keeping our minds open to things that may not have been brought to the forefront yet.

"Notice I didn't say we might have developed a preference along the way," said Aaron. "It's awfully easy to think of the initiatives presented in the Ride Report as if they are in a race and we'll pick one and drop the others. I think it's very likely as we go toward the future that we'll do a blend of the initiatives. What the agency is trying to achieve is the right blend of these thrusts as opposed to one over the other."

What the final mix of goals is will depend largely on the outcome of the public debate. "It really isn't NASA's role to state the goals," said Ladwig. "And that's historically how NASA has operated. Most NASA administrators have not wanted to be the one to articulate the goal; they felt that was at the discretion of the president and Congress. We are but instruments of achieving that goal."

Aaron believes the climate that decision will be made in may change during the coming years. The concern over tight federal budgets is one thing that could change. "Given that the next few years are years of investing in technology for these programs, you almost have to look beyond what the current set of fiscal constraints are. Assume that Gramm-Rudman has been successful, that the federal budget is in line in the next few years. You have to 'crystal ball' what's going to happen in the mid to late '90s, what the outlook will be then, so you can project what kind of decision might be made in '91 or '92," said Aaron.

"I think the issue will not be just a fiscal one. I don't think the initiatives we're talking about are out of fiscal reality if there's a national sense that we want to do them. The question will be to what degree there is a national thought process that says continued leadership in space is important for national leadership as well as for the overall prestige of the nation.

"In the 1990s and beyond, any major world country that is an international leader will have a major space element as part of its national policy. What direction the United States takes with its space program may have more to do with an awareness of that fact and a national sense of leadership than with fiscal limitations."

— Stephen Cole

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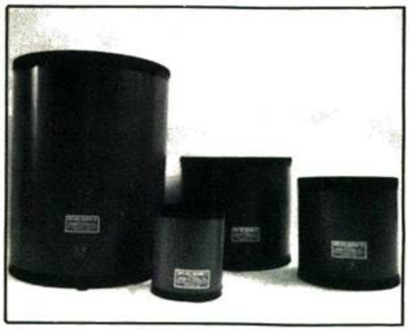

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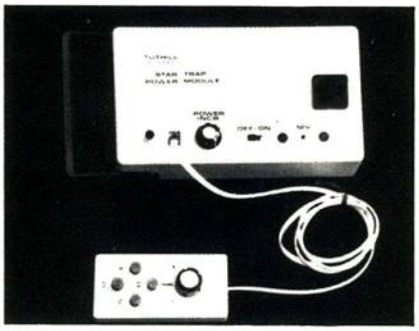

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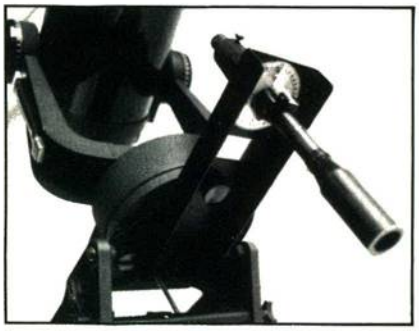

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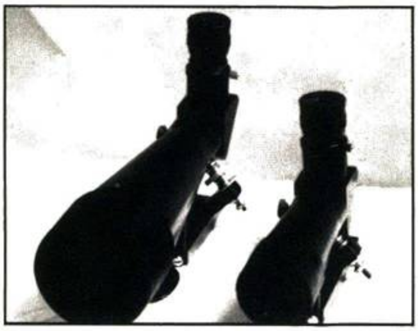

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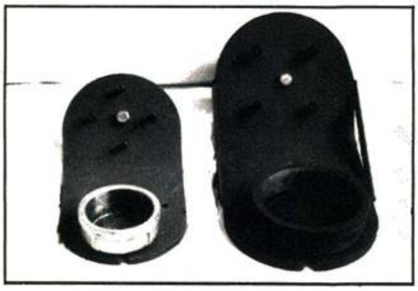

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ASTRONOMY
In Focus

'Cleaning Up' Space Debris

Sir / In "The Impending Crisis of Space Debris" by Joseph A. Lovece (August 1987), there were a few errors I wanted to correct.

- Only one hand tool ever floated in space, and it is no longer in orbit.
- Two satellites, *SDI1* and *SDI2*, impacted each other during a test in an intentional maneuver; they were not "blown up."
- Because orbital lifetimes depend on the object's size, mass, cross-sectional area, orbital perigee, orbital eccentricity, and solar activity levels, it is incorrect to state that an object "at 500 miles . . . will remain in orbit for thirty years."
- The European Space Agency's *Geos 2* spacecraft has not been "battered by space junk" and is unlikely to be battered because it is in geosynchronous orbit.

Geoffrey Falworth
Editor, *Satellite News*
Preston, England

Computer-Plotted Star Maps

Sir / I enjoy your astronomical programs for personal computers. Although I own a TRS-80, I am usually able to convert the BASIC language used in the programs to a language that works on my computer.

However, about two years ago you published a program for star maps ("How to Plot Star Maps on Your Computer" by Richard Berry, Equipment Atlas, August 1985). On line 60 you state that the YHT value for the IBM is .38. What would the value be for the TRS-80 with a 256x192 graphics screen?

Eric Pietersma
Iroquois, Ontario, Canada

— YHT controls the height-to-width ratio of the star map plotted on the screen. The easiest way to evaluate this is experimentally. Make a small database with a dozen or so stars arranged at the same declination (say +60°) and then plot a pole-centered map. Adjust YHT until the stars form a circle on the screen.

Perseids Better than Expected

Sir / The prospects for this year's Perseid meteor shower were not favorable because of the nearly Full Moon. But I decided to observe the shower anyway to see how many meteors I could see.

Even though the Moon was a few days past Full, I saw seventy-five meteors (fifty-eight Perseids and seventeen sporadics) within four hours and fifteen minutes in the predawn skies of August 11, 12, and 13. Although the rates were probably lower than they would have been under more favorable, moonless conditions, they seemed higher than one might expect.

One explanation for the high number of meteors was that perhaps this *was* a good year for the Perseids. If I hadn't gone out to see for myself, I might still believe the shower wasn't worth watching.

George W. Gliba
Greenbelt, Maryland

Don't Be a Lone Wolf

Sir / The only thing I would add to Bill Volkart's "Do Your Homework before You Buy" (October 1987) is the importance of getting together with others who share your interest in astronomy. When you go out observing with people more experienced than you are, you can get advice about selecting a telescope.

By observing with a local organization of amateur astronomers, you can get a good idea of how different telescopes perform. Members are always happy to let you look through their instruments and enjoy talking to you about their telescopes.

A few years ago when I started out, I almost bought a department store refractor. Thank goodness I had enough sense to take the advice of someone who knew about telescopes. I now have a telescope that is just right for me.

Victor Wolf
Columbus, Ohio

— See ASTRONOMY's Summer Travel Guide (June 1987) for a list of astronomy clubs in the United States and Canada.

Another Victim of Light Pollution

Sir / I agree with Thomas King's letter (In Focus, October 1987) about saving Palomar Observatory from light pollution. We cannot afford to see another major installation for research in astronomy moth-balled.

The David Dunlap Observatory of Richmond Hill, Ontario, just north of Toronto, will soon face the fate of Mount Wilson, because of the rapid growth of Toronto and the surrounding cities. Area politicians are permitting new subdivisions to be built within one hundred meters of the observatory's main telescope!

Let the amateur astronomers of the world show that we will not tolerate the loss of professional astronomical facilities to irresponsible local politicians. If enough of us speak out, we can stop the growth of light pollution around Palomar Observatory.

Derek Holt
Waterloo, Ontario

The Reflector Advantage

Sir / Several important points regarding the refractor versus reflector controversy were not dealt with adequately in "The Refractor Advantage: Quality over Size" by Alan Dyer (October 1987). Mr. Dyer glosses over the fact that per dollar spent, Newtonian reflectors are superior to refractors in both light-gathering power and resolution.

For the price of a high-quality 3-inch refractor one can obtain a high-quality 6- or 8-inch Newtonian reflector. That 3-inch refractor will certainly be superior in every way to any *3-inch* reflector, but it won't even come close to a quality 6- or 8-inch Newtonian in any area of performance.

Karl Fabian
Chicago, Illinois

Science Fiction Isn't Fantasy

Sir / As a professional science fiction writer with a degree in both astronomy and physics, I resent Peter W. Mills' comments that Project Daedalus, discussed in your two-part "Star Trek" feature, "eliminates the science fiction element" because Daedalus used "present day technology or technology that could reasonably be developed from presently available systems" (In Focus, October 1987).

This attitude surprised me, because that is exactly what good science fiction attempts to do — extrapolate current technology into a plausible future according to our present understanding of science. Without such an attempt at scientific plausibility, the story becomes fantasy, not science fiction.

Because popular science fiction has done so much to captivate and promote interest in astronomy and space science, many science fiction writers are growing tired of this mistaken attitude on the part of the professional community. Every scientist knows the necessity of checking the facts.

The only way Project Daedalus differs from good science fiction is that science fiction is a story wrapped in a detailed technologically feasible scenario; Project Daedalus is such a scenario but without a story.

Kevin J. Anderson
Lawrence Livermore
National Laboratory
Livermore, California

Wrist Watch for Observing

Sir / New liquid crystal digital wrist watches, which can store a list of fifty names, telephone numbers, and schedule reminders, can be used by amateur astronomers to store the names, types, magnitudes and coordinates of fifty favorite deep-sky objects.

A typical entry on my watch reads: M22G6 18 34 −25 37, which tells me M22 is a globular cluster of magnitude 6 located at right ascension 18h34m and declination −25°37′. The watch automatically stores entries in alphabetical and numerical order for easy reference. Coordinates can be read directly from the watch, which decreases the need for cumbersome atlases, charts, and lists at the telescope. A built-in light illuminates the display without impairing night vision.

Rod Pommier
Portland, Oregon

Uranometria 2000.0 Lacks Double Star Numbers

Sir / I just received my copy of *Uranometria 2000.0*, volume one. For those who enjoy observing deep-sky objects other than double stars, the atlas identifies the objects by catalog number and sometimes by common name. The deep-sky observer only has to look up an object by catalog number to determine if the object is worth observing under the existing conditions.

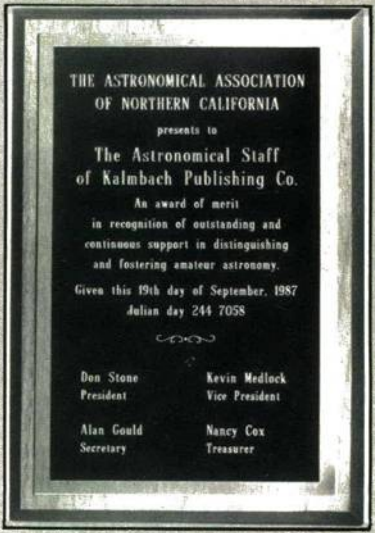
However, for double star observers the atlas presents a predicament. Double stars are plotted with a line bisecting them. This is certainly helpful, but without an identifying catalog number, I find myself working at the telescope with both the atlas and a catalog, trying to determine whether a given double star can be observed or not.

I can only dream of the day when some cartographer publishes an atlas that identifies the double stars marked in *Webb's Celestial Objects for Common Telescopes*, volume II.

Jim Phillips
Charleston, South Carolina

Behind the Scenes

AANC Presents Award to Kalmbach



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The Astronomical Association of Northern California this year cited ASTRONOMY's parent company, Kalmbach Publishing Co., for its contributions in support of amateur astronomy. Don Stone, president of the AANC, presented the award during the AANC meeting held on September 18-19, 1987, at the Lawrence Hall of Science in Berkeley, California.

"You don't publish just one magazine," said Stone, "but four magazines for different readers. With *Telescope Making* for the mechanically inclined and *Deep Sky* for the observers, you satisfy advanced amateur astronomers.

"*Odyssey* provides a unique service to the astronomy field by making available high-quality information about space and astronomy to people in an age range for which there's little else that's well done.

"ASTRONOMY is excellent for beginners and intermediate-level amateurs," he said, "and it's very important to have a magazine like that. It brings lots of new people into amateur astronomy."

On behalf of Kalmbach's entire astronomical staff, both past and present, I would like to thank the AANC for this award and pledge our continuing support to amateur astronomers everywhere.

When managing editor Steve Cole and I first read Sally Ride's *Leadership and America's Future in Space*, we were so impressed with the cool, clear logic of the report that we decided to devote this issue of ASTRONOMY to presenting the report to our readers. Our coverage includes extensive portions of the report, a feature article on where each of the four Ride Report initiatives now stands, and an interview with John Aaron, the head of NASA's newly created Office of Exploration, who is charged with furthering the ideas in the report.

The most important factor in determining America's future in space is the American public, that is, you. Make your voice heard by filling out and returning the Reader Poll on page 23. We will report your responses and comments in the May issue.

Sincerely,

Richard Berry

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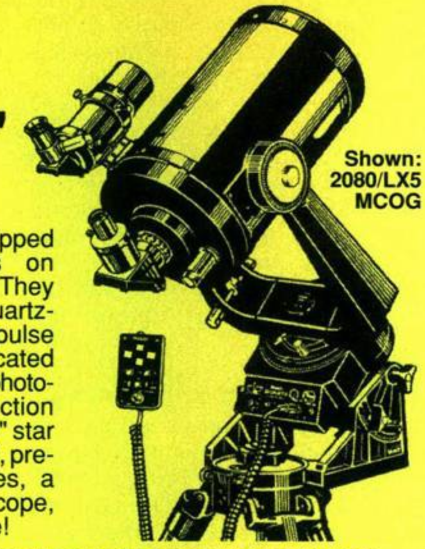
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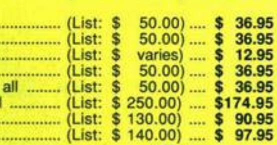

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Electric Declination Motor, for PS-C8 II	(List: $ 130.00)	**$ 89.95**
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T-Adapter for camera, for C8 Tubes	(List: $ 40.00)	**$ 29.95**
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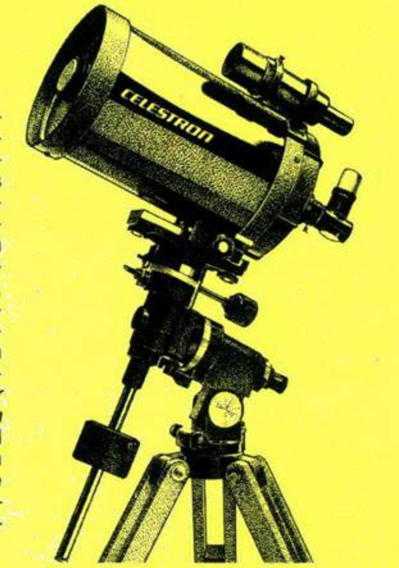

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SP-C8	(List: $1,620)	**$ 949.95**
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ASTRONOMY

Reviews

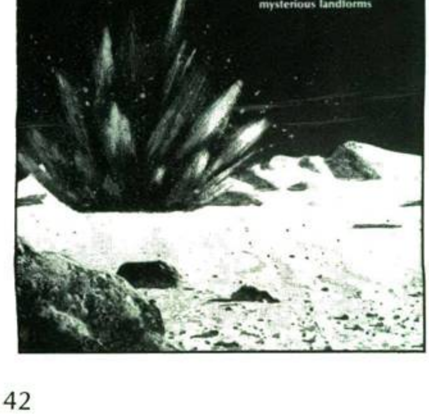
The Origins of Earth's Craters

Meteorite Craters by Kathleen Mark, (University of Arizona Press, 1987), ISBN 0-8165-0902-6, hardcover, 288 pages, $29.95.

Without our planet's healing winds and waters, approximately 100,000 craters larger than Arizona's meteor crater would scar the surface of Earth. Furthermore, there would be untold numbers of minicraters, which would make our planet resemble its pockmarked satellite.

Nonetheless, it wasn't until the middle of this century that evidence led some — but not all — investigators to conclude that craters on Earth were of meteoric origin.

In an attempt to synthesize the history of this relatively young science, Kathleen Mark has produced a readable, authoritative book that most readers will find interesting and enlightening. *Meteorite Craters* is a scholarly description of the often controversial investigations of craters presumed to be of meteoric origin. Though it's precisely documented, Mark's book is nontechnical and clearly written. In addition to eleven pages of chapter notes, the volume boasts twenty-five pages of references and more than sixty illustrations and photos.


KATHLEEN MARK
Meteorite Craters
How scientists solved the riddle of these mysterious landforms

In addition to describing prominent craters, the author discusses the work of early U.S. researchers (many of whom were interested laymen). Mark also addresses impact characteristics, pertinent landforms, metamorphism (alteration of rock composition by heat or pressure), and cryptovolcanic structures associated with crater research. The latter term, coined in 1905, describes volcanoes that did not quite break through the Earth's surface, often confusing researchers in their quest for meteor craters.

Arizona's 4,000-foot wide meteor crater, also known as Barringer Crater, is probably the best known example of craterforms on Earth. Mark focuses a significant amount of her book on this crater. Initially thought to be the product of a gigantic steam explosion, the popular crater has been drilled, mined, assayed, and intensively studied. By 1920 many scientists were convinced that the huge depression was indeed formed by a huge projectile from space. According to the author, the assumption was that "if one meteorite crater existed on the surface of the Earth, no doubt there were others." This was proved to be true.

Mark injects anecdotal material when appropriate, which punctuates the greater story of crater research with humor and irony. For example, because the treeless plains of western Kansas are mostly devoid of rocks, the author writes about cowboys occasionally finding uncommonly heavy black stones that they used for weight lifting. Other mundane uses for the celestial rocks included weighing down haystacks and Kansas rain-barrel lids.

In one sense the book resembles a detective story. The reader is presented with a geological mystery, such as the origin of glasslike tektites — small, round glassy objects found only in certain parts of the world. Mark leads us vicariously through several possible explanations for the existence of these structures, which apparently formed by the rapid cooling of molten material: volcanism, powerful shock waves, presumed ancient glass factories in Europe, and fusion by lightning. Finally we arrive at the generally accepted terrestrial origin for tektites: they formed by the fusion of terrestrial material splashed from the impact of a giant meteorite.

Also described are studies regarding the depth-diameter relationship of terrestrial craters, both manmade and those of meteoritic origin. These studies show that lunar craters were not the result of volcanic action. Thus, lunar craters were ostensibly created by meteoritic bombardment, and the evidence suggests that Earth's were also created that way.

Mark's final statement is too modest for the breadth and authority of her book. She writes, "And so it was that the investigation of some holes in the ground led eventually to a small increase in our meager knowledge of the astonishingly wonderful universe in which we live."

The study of terrestrial craters of meteoritic origin continues. For an accurate, well-researched introductory overview of the field, you could not find a better book.

— *Gail O. Clark*

To the Ends of the Universe

Light from the Depths of Time by Rudolf Kippenhahn (Springer-Verlag, 1987), ISBN 0-387-17119-3, paperback, 262 pages, $19.95.

The late George Gamow wrote three excellent books on atomic physics that featured a certain Mr. Tompkins, who was the embodiment of all naive readers. In these books Gamow arranged for Mr. Tompkins to experience many seemingly strange things that brought to light various aspects of atomic physics. In a similar vein, German astrophysicist Rudolf Kippenhahn has invented Herr Meyer, who in his turn encounters strange things and who allows the author to explore the universe in ways that are impossible in reality — through intergalactic spaceflight, for instance.

While Kippenhahn's earlier book, *100 Billion Suns* (Basic Books, 1983) was about stellar evolution, this work focuses on galaxies and cosmology. It begins with an overview of the Milky Way Galaxy. Herr Meyer takes a jaunt out to the Virgo Cluster and returns to his armchair by way of the galactic core. On the way we get a foretaste of how weird some galaxies can be (M87, for example), and we take a quick look at the center of the Milky Way Galaxy.

Chapter two is about light, or rather the entire electromagnetic spectrum. Herr Meyer falls asleep and dreams of visiting a radio station with a transmitter that is continuously tunable over a remarkable range of frequencies — radio to gamma rays! Along with Herr Meyer we discover what happens when you shift the broadcast frequency from radio toward the shorter wavelengths. The antenna starts off looking dark (radio frequencies are invisible, of course) and then begins to change as we tune the transmitter toward the visible part of the spectrum. It glows red-hot at first, then yellow, then blue, and then it darkens again. Herr Meyer is puzzled by this, but the station engineer hurriedly hands him a lead apron and an explanation. Fortunately before they absorb a lethal dose of gamma rays, the system short-circuits and Herr Meyer wakes up in his living room chair. To round out the lesson, Kippenhahn shows us how both continuous and line spectra are created and what they look like to the Earthbound observer. The chapter ends with an explanation of the interconnection of energy and matter.

With these basics outlined, the author next takes us a short distance out of the Galaxy to view our star system in accelerated time — 100,000 times faster than normal. Variable stars flicker rapidly and supernovae turn on, blaze for a few seconds, and then fade out. But the Galaxy itself seems motionless. Then the author speeds up the view until it's a billion times faster than normal. At this pace, hundreds of supernovae flash every second and the Galaxy begins to rotate ponderously. Herr Meyer sees stars and gas flowing into the density waves that mark the spiral arms where hot blue stars rapidly form and shine brightly. Dozens of globular clusters sail through the galactic disk and coast out to great distances. There they slow down, turn around, and fall back through again.

The picture Kippenhahn draws of this "galactic machine" is vivid and highly memorable. I suspect any astronomy educator would give his right arm to have an animated film of this chapter.

In chapter four, which covers methods of determining distance, the author switches to a historical approach that he maintains throughout the rest of the book. Starting at roughly 1900, we learn about cosmology as astronomers themselves did. We see how in the first two decades of this

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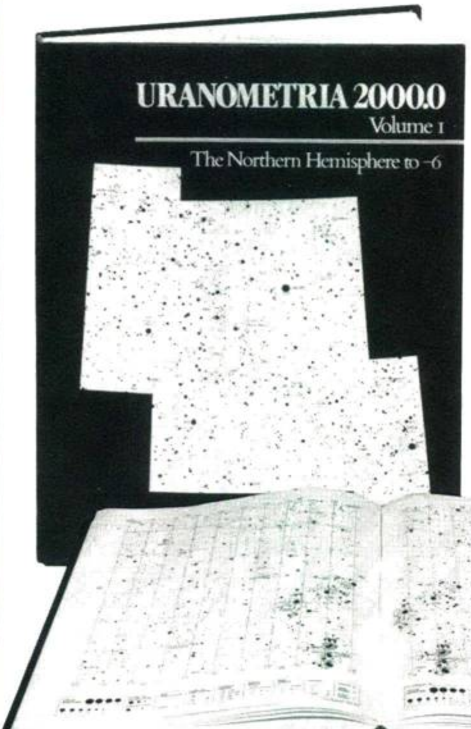
URANOMETRIA 2000.0 Volume 1 The Northern Hemisphere to -6°



By Wil Tirion, Barry Rappaport, and George Lovi

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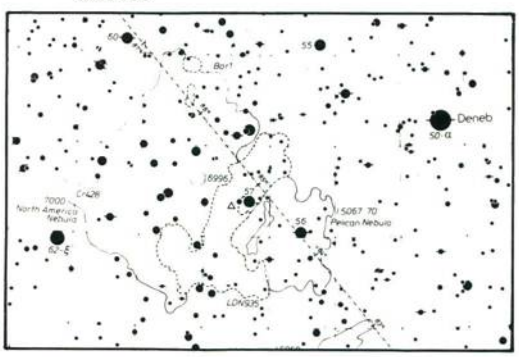

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century Henrietta Leavitt's period-luminosity relation for Cepheid variables led directly to Harlow Shapley's discovering that the solar system wasn't at the center of the Galaxy.

But the big question among astronomers was: What is the Galaxy? Is it like the "Great Nebula" in Andromeda (M31) or something wholly different? Observations weren't much help because they could be construed to support either view. Though he was right about the solar system's location in our Galaxy, Shapley picked the losing side of the argument. Heber Curtis of Lick Observatory was convinced that our Galaxy and M31 were the same kind of object with a vast distance between them; Shapley, using evidence of large-scale motions in spiral nebulae, argued that M31 was relatively nearby and differed from our own Galaxy.

In 1920 Curtis and Shapley held an inconclusive debate on the subject; four years later the matter was resolved when Edwin Hubble found several Cepheid variables in M31. The period-luminosity relation showed that M31 was quite distant and the large-scale motions were shown to be errors in measurement.

Around this time it was becoming clear that relativity had a lot to say about cosmology. To help us understand the debates about the shape and size of the universe, Kippenhahn takes Herr Meyer off to Flatland, that two-dimensional geometrician's paradise invented by Edwin Abbott. After translating our astronomy into Flatlander terms — for example, the Flatland night sky is a long string with bright beads on it — Kippenhahn shows how the Flatlanders' universe might actually be corrugated though its inhabitants could never verify this by observation. It's a neat trick that sets us up for understanding why the real universe can have a structure that's imperceptible to us in three dimensions.

Chapter nine examines the types of galaxies that exist and their placement in space (clusters, strings, superclusters, etc.). Chapter ten is about radio astronomy and its findings. Chapter eleven focuses on quasars, including their central engines and "superluminal" expansions. Chapter twelve deals with the microwave background, the last dim vestige of the Big Bang, redshifted nearly to oblivion. These chapters cover topics that have already become well-established parts of astronomy's intellectual landscape even though they're fraught with novelty.

For me, the last chapter was the most interesting and thought-provoking. In "The Intelligent Universe" Kippenhahn discusses a few implications of what we've learned. For example, many people wonder what came before the Big Bang. But the very question is tautological. Kippenhahn notes that physics has nothing to say about what went on before the Big Bang because only *after* the Big Bang did the universe become describable by physics.

He also asks if natural laws have determined the form of the universe. Many of us might agree to this proposition without question. But Kippenhahn interestingly answers: No, natural laws haven't done this, except in a fairly trivial sense. Our "laws," he said, simply codify our limited experience; the universe can do whatever it likes. As we discover more and more phenomena, we'll just fiddle with our laws until they don't contradict what we see. But to think these laws somehow bind the universe at large is silly. On the contrary, Kippenhahn argues strongly that the laws of nature have no existence outside of our own minds. He freely admits that many of his colleagues disagree. They feel physical laws are real, because they've entered the universe with the Bang and have been there ever since. The book offers no resolution; Kippenhahn simply makes his position clear. I wish I knew my own mind well enough to do the same!

In any case this is an intriguing book. Its diagrams are well done and the translation (by Storm Dunlop) reads easily while never losing its European accent. The index is a disappointment because it leans too heavily on personal names at the expense of analytical detail. However, this flaw is relatively minor in a work that is excellent overall.

— *Robert Burnham*

Astrophysics

Annual Review of Astronomy and Astrophysics, edited by Geoffrey Burbidge, (Annual Reviews, Inc., 1987), ISBN 0-8243-0925-1, hardcover, 684 pages, $44.

Astronomy and Astrophysics Abstracts, edited by S. Bohme, U. Esser, H. Hefele, I. Heinrich, W. Hofmann, D. Krahn, V. R. Matas, L. D. Schmadel, and G. Zech, (Springer-Verlag, 1987), ISBN 3-540-17898-8, hardcover, 1,169 pages, $129.

Astrophysical Jets and Their Engines, edited by Wolfgang Kundt, (D. Reidel, 1987), ISBN 90-277-2548-9, hardcover, 256 pages, $59.50.

Astrophysics and Space Physics Reviews, volume 5, edited by R. A. Syunyaev, (Hardwood Academic Publishers, 1987), ISBN 3-7186-0214-8, hardcover, 260 pages, $170.

Cataclysmic Variables: Recent Multi-Frequency Observations and Theoretical Developments, edited by H. Drechsel, Y. Kondo, and J. Rahe, (D. Reidel, 1987), ISBN 90-277-2435-0, hardcover, 805 pages, $124.

Dynamical Astronomy: Proceedings of the Second U.S.-Hungary Workshop, edited by Victor G. Szebehely and Bela Balazs, (University of Texas Press, 1986), ISBN 0-292-71507-2, hardcover, 177 pages, $25.

Galaxy Distances and Deviations from Universal Expansion, edited by Barry F. Madore and R. Brent Tully, Series C: Mathematical and Physical Sciences, volume 180, (D. Reidel, 1986), ISBN 90-277-2277-3, hardcover, 301 pages, $64.

Gravitational Physics of Stellar and Galactic Systems by William C. Saslaw, (Cambridge University Press, 1987), ISBN 0-521-34975-3, paperback, 491 pages, $34.50.

Inner Space/Outer Space: The Interface between Cosmology and Particle Physics, edited by Edward W. Kolb *et al.*, Theoretical Astrophysics series, (University of Chicago Press, 1986), ISBN 0-226-45033-3, paperback, 638 pages, no price given.

Interstellar Magnetic Fields: Proceedings of a Workshop, Tegernsee, 1986, edited by R. Beck and R. Grave, (Springer-Verlag, 1987), ISBN 3-540-17751-5, hardcover, 273 pages, $45.40.

Jacobi Dynamics by V. I. Ferronsky, S. A. Denisik, and S. V. Ferronsky, (D. Reidel, 1987), ISBN 90-277-2418-0, hardcover, 365 pages, $84.

Light on Dark Matter: Proceedings of the first IRAS Conference, the Netherlands, 1985, edited by F. P. Israel, Astrophysics and Space Science Library series, volume 124, (D. Reidel, 1986), ISBN 90-277-2254-4, hardcover, 541 pages, $98.

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The Riddle of Gravitation by Peter G. Bergmann, (Charles Scribner's Sons, 1987), ISBN 0-684-18460-5, hardcover, 233 pages, $18.95.

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Structure and Evolution of Active Galactic Nuclei: Proceedings of the European Physical Society, Italy, 1985, edited by G. Giuricin *et al.*, Astrophysics and Space Science Library, volume 121, (D. Reidel, 1986), ISBN 90-277-2155-6, hardcover, 772 pages, $99.

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The Symbiotic Stars by S. J. Kenyon, (Cambridge University Press, 1986), ISBN 0-521-26807-9, hardcover, 288 pages, $54.50.

Very High Energy Gamma Ray Astronomy, edited by K. E. Turver, (D. Reidel, 1987), ISBN 90-277-2459-8, hardcover, 398 pages, $69.

General Interest

Astronomy: A Self-Teaching Guide by Dinah L. Moche, 3rd edition, (John Wiley & Sons, 1987), ISBN 0-471-85297-X, paperback, 291 pages, $12.95.

Nobel Dreams: Power, Deceit, and the Ultimate Experiment by Gary Taubes, (Random House, 1986), ISBN 0-394-54503-6, hardcover, 261 pages, no price given.

Stars, Galaxies, Cosmos: A Catalog of Astronomical Anomalies, compiled by William R. Corliss, (Sourcebook Project, P.O. Box 107, Glen Arm, MD 21057, 1987), ISBN 0-915554-21-6, hardcover, 240 pages, $17.95.

Solar System

Meteorites and Their Parent Planets by Harry Y. McSween, Jr., (Cambridge University Press, 1987), ISBN 0-521-32431-9, hardcover, 237 pages, $24.95.

Harry Y. McSween, Jr., traces the genealogy of meteorites back to the asteroids and planets they came from. McSween delves into geology, chemistry, physics, and astronomy to explain how scientists study chondrites, achondrites, and iron and stony-iron meteorites and determine where they come from.

The book is arranged with a chapter on the meteorite type, followed by a chapter on its parent body. Though the explanations of the scientific processes get too detailed at times for the nonscientist, McSween succeeds in unlocking the mystery of solar system rocks that are blasted to our planet. The significance of meteorites, he points out, is that as pieces of the early solar system, meteorites provide clues to the origin and evolution of our solar system.

The book is intended for the general reader and includes a glossary of all technical terms and an extensive annotated bibliography at the end of each chapter.

— *Kristine R. Majdacic*

Comet Predictions for 1988 and 1989 by Charles Townsend, John Rogers, and Chris Spratt, (Project Sky Scan, 3521 San Juan Avenue, Oxnard, CA 93033, 1987), pamphlet, 40 pages, $7.

Observations of Comets from 611 B.C. to A.D. 1640: Extracted from the Chinese Annals by John Williams, (Science and Technology Publishers, Ltd., reprint of 1871 book), hardcover, 124 pages, 52 British pounds.

Orbits for Amateurs with a Microcomputer, volume II, by D. Tattersfield, (John Wiley & Sons, 1987), ISBN 0470-20356-0, hardcover, 159 pages, no price given.

Photochemistry of the Atmospheres of Mars and Venus, edited by Vladimir A. Krasnopolsky, Physics and Chemistry in Space series, volume 13, (Springer-Verlag, 1986), ISBN 0-387-15336-5, hardcover, 334 pages, $90.

Physics of the Sun, Volume I: The Solar Interior, edited by Peter A. Sturrock, *et al.*, Geophysics and Astrophysics Monographs, (D. Reidel, 1985), ISBN 90-277-1860-1, hardcover, 257 pages, $44.50.

Predictive Ephemerides for Selected One-Apparition Periodic Comets (1987 to 2000) by Charles Townsend and John Rogers, (Project Sky Scan, 3521 San Juan Avenue, Oxnard, CA 93033, 1986), pamphlet, 54 pages, $6.

The Sun and the Heliosphere in Three Dimensions: Proceedings of the 19th Eslab Symposium, Switzerland, 1985, edited by R. G. Marsden, Astrophysics and Space Science Library, volume 123, (D. Reidel, 1986), ISBN 90-277-2198-X, hardcover, 525 pages, $79.

The Tucson Meteorites: Their History from Frontier Arizona to the Smithsonian by Richard R. Willey, (Smithsonian Institution Press, 1987), ISBN 0-87474-983-2, paperback, 47 pages, $8.95.

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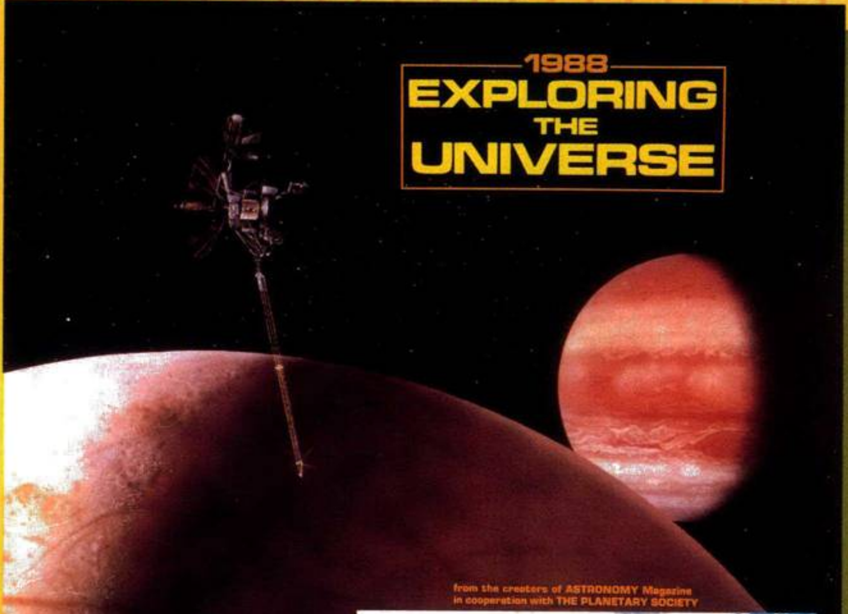
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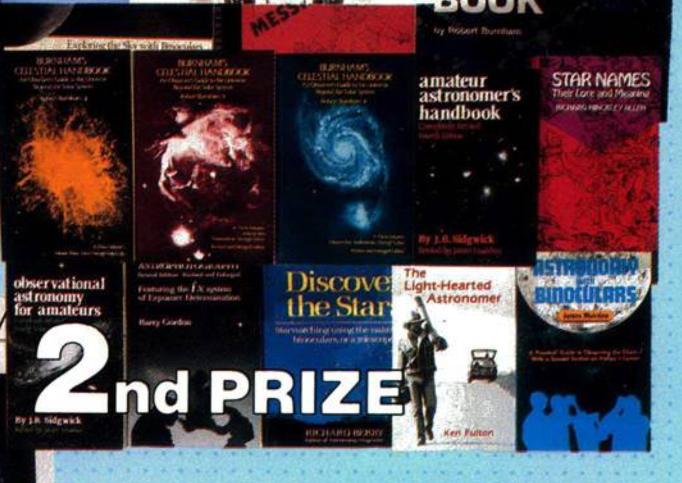

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Should You Keep an Astronomical Notebook?

by Andrew M. Thorpe

Conscience: *"You know, you really should keep a record of what you've seen in the sky."*

Observer: *"I know, but it's so darn much work to keep notes on all of my observations. It takes more time than observing does!"*

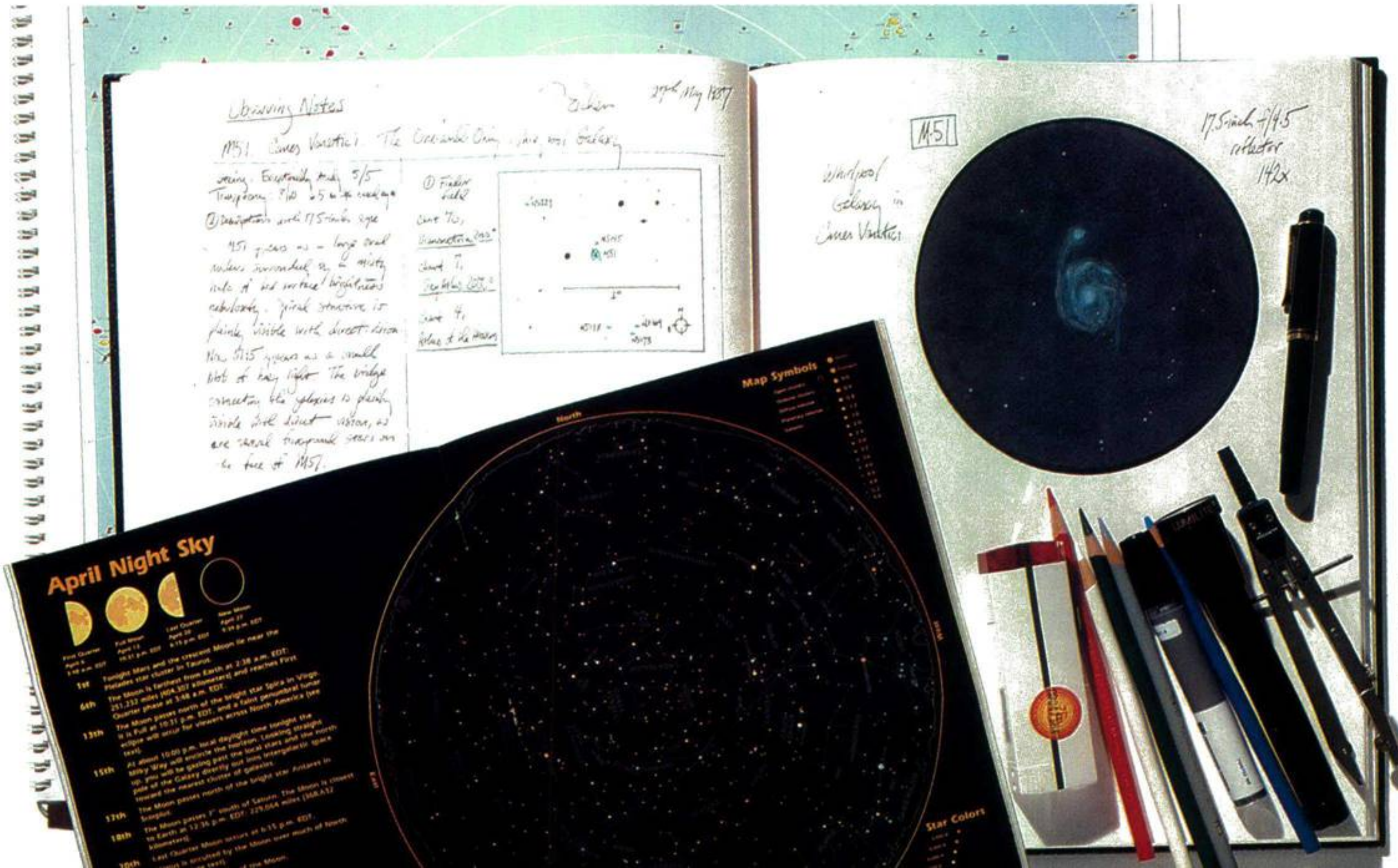
If you've observed the sky for a number of years, you've probably experienced the mental tug of war all observers struggle with over keeping a journal of observations. Maintaining a notebook may seem like a waste of time when, after all, you could be observing much more if you weren't writing down your impressions of the sky.

But an astronomical notebook provides significant benefits you may not be able to see right away. Keeping a notebook makes a more satisfied observer. It will remind you of all the things you've seen, the way you felt while observing, and the frustrations and successes you've had with the hobby. And, most importantly, it will prompt you to observe more carefully and to see more when you observe.

A notebook is your private record of the universe. Not only will it remind you of objects you have seen but of special events like meteor showers, a fantastic fireball you spotted, or an eclipse. A notebook gives you a place to collect sketches you make of galaxies, nebulae, and planetary detail and to write down your impressions to savor later on. Yes, keeping a notebook requires some attention to detail and a healthy dose of perseverance. But who can put a price on the result after ten or twenty seasons of journal keeping?

So that your journals last over years of use, I recommend using hardbound notebooks. You could get an octavo-size book, approximately 6" by 9.5", if you want portability. If you want more room on the page, get a standard quarto-size (8.5" by 11") notebook. If you plan to make lots of sketches or extensive notes and portability is not a consideration, try a small folio-size (about 11" by 14.5") sketchbook.

If you want to use ruled paper, try an office supply store or a scientific supply house. A place like this usually offers hardbound laboratory or accounting notebooks with printed vertical rules or a quadrille pattern that keeps notes looking neat. Quadrille books will prove invaluable if you should decide to add details like graphs or plots that show the bright-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ness changes of variable stars you've observed.

The second type of notebook is a plain, bound book of blank pages, available as a diary book at a bookstore or as a sketchbook at an artist's supply store. Artist's sketchbooks are large: if you want to make large, detailed drawings of objects, this type of notebook is for you.

Once you have a notebook, how do you set it up? I suggest arranging your observations chronologically, as if you were keeping a diary. Each night you can write a short introductory description of the sky and yourself. It might read something like this: "July 9, 1987. 10:15 p.m. EDT. Hawthorne, New Jersey, regular site. The sky looks crystal clear and the seeing appears steady, because I don't see any twinkling of stars near the horizon. However, I'm tired from observing all night last night, so tonight will be a short session."

The first rule of notebook keeping is to record *everything* that seems even remotely relevant. It's better to record too much information than a few scant bits. For example, recording personal feelings may seem off the path of the observation, but it isn't. If you're tired from observing on a previous night, upset over troubling news, or fatigued from lack of food, your observations can be greatly affected. So in setting up the basic information before recording observations, don't shy away from describing your mood and physical state.

Some basic information should be included with any observation. This basic data includes the date, time, observing location, transparency, and seeing conditions. These data are simple and straightforward once you understand how to judge the sky's transparency and the quality of seeing.

Astronomers usually rate sky transparency and seeing on a scale of zero to ten. Transparency refers to the amount of particles in the atmosphere: if the sky has zero transparency, it is cloudy, and if it has a transparency of ten, the sky is as free from haze or water vapor as it possibly can be. Transparency greatly affects the faintest stars you can see, because a little haze can wipe out great numbers of faint stars. Estimating the faintest star visible with the naked eye is one way of gauging the relative transparency.

Seeing refers to the atmospheric steadiness. If the seeing is terrible — a zero on the scale — stars will twinkle and faint stars will be rendered invisible by turbulent air. If the seeing is good and the atmosphere perfectly steady — a ten on the scale — stars will appear as stable, crisp images set against a black background.

Accurately rating transparency and seeing for your site will take time and practice. Get to know the sky and its range of conditions, make an estimate on the zero-to-ten scale, and don't fret too much about being "right." After all, you're the person your notebook is for!

You'll want to include complete information about the telescope and magnification you've used for an observation. This should include the telescope's aperture, focal ratio or focal length, eyepiece type, and magnification. It may seem like a bother to write these facts down for each observation, but as time passes, trying to remember these things without a record is nearly impossible, especially if you use more than one telescope.

The observing information you'll want to record depends on the types of objects you view. Planetary detail constantly changes in subtle shades of gray, orange, yellow, and cream. Jupiter's cloud belts often show easily visible variations that you can follow with a 4-inch telescope. Once I followed a storm that lasted for three nights as it rapidly changed in size and intensity. My observations show that the Great Red Spot affects weather patterns on a planet-wide scale: the appearance of festoons and swirls is dramatically altered near the leading and following edges of the spot. I collected all of these objects by sketching the observations and explaining them in words.

By all means keep an observing notebook. It will soon contain unique records of your journey through the universe.

The atmosphere of Mars is active during each opposition, especially in the planet's polar regions and in the high latitudes of the Tharsis Ridge. White clouds in the Tharsis region are quite difficult to see, however. When observing such subtle features, record everything you can see and make a note if you merely "suspect" something or think you may see it. Make the distinction between an observation and a suspicion clear.

Variable star observing requires you to make careful comparisons with stars of constant brightness and record estimates of the variables' magnitudes. The American Association of Variable Star Observers produces and sells finder charts for hundreds of different variables. These should be included in your notebook so you can pull them out for quick reference. For short-period stars, make sure you record the time you make the estimate. An observation without that fact could be essentially useless. For all variables, record the brightness of the variable star and make a little sketch of the surrounding field, showing the comparison stars you used and their brightnesses. If you are using a preprinted chart like those available from the American Association of Variable Star Observers, you don't need to draw a comparison star diagram. (For information on variable star charts, write the AAVSO at 25 Birch Street, Cambridge, MA 02138).

If you want to make observations of deep-sky objects, you must become adept at describing many different objects that may appear remarkably similar if you have a small telescope. Therefore, it's important to observe details with a keen eye and practice seeing subtle differences in objects. When observing nebulae and galaxies, look for the overall distribution of brightness, the concentration of light toward the center, stars that may be superimposed on the object, evidence of spiral arms or asymmetrical structure, and any other features you can discern.

Record all these features carefully by writing a concise paragraph about the object. For star clusters, look for features like numbers of stars, star colors, brightnesses of stars, noticeable patterns, concentration toward the center, and overall cluster shape. It is the attention you pay to writing that makes you a keen observer. You will soon learn to see more, and the "faint fuzzies" will soon become detailed objects to your notebook-trained eye.

Whether or not you dabble with it at first, you should eventually sketch objects at the telescope. By embellishing your written notes with a visual picture of the observation, you'll create a precise image of what the view was like for anyone who sees the notebook in the future. Sketching the planets and deep-sky objects is really not as difficult as it may seem at first. You'll need a compass or template for drawing circles, a fine black ink pen, a soft pencil (an Eberhard Faber Ebony pencil is perfect), and the patience to try many sketches before getting one that really convinces you.

To sketch a planet, simply draw a circle that conforms to the shape of the planet's disk, and then slowly and carefully add the details visible on the planet's surface. Try to draw them softly and smoothly, and you'll come away with a convincing portrait. Too many planetary sketches contain hard lines and strokes that make the sketches appear unrealistic. For deep-sky objects, lay down some graphite and smear it to resemble the shape of the object. Then add details to complete the nebula or galaxy. Finally, add the stars visible in your telescope's field of view.

If you become good at sketching and want to create a very realistic set of planetary or deep-sky images, get some ink markers and a set of colored pencils. With these tools you will be able to draw black circles (with the markers) and sketch in color on top of the black surface. This is a powerful technique that can produce stunningly realistic results if practiced and used with caution.

By all means keep an observing notebook. Although at first you may have to adjust to updating it, the notebook will eventually contain unique records of your journey through the universe. Astronomy offers great personal satisfaction. It would be a shame if all those wonderful memories of your involvement with astronomy simply faded away with time.

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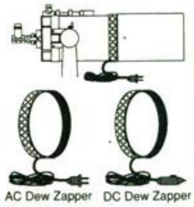

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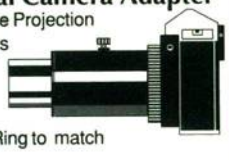

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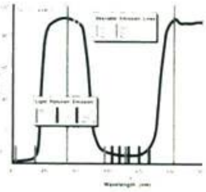

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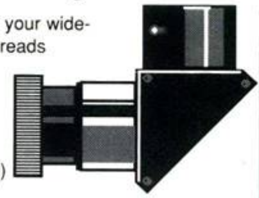

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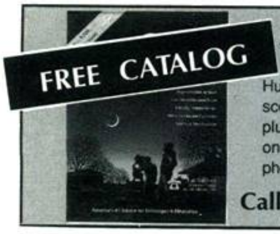

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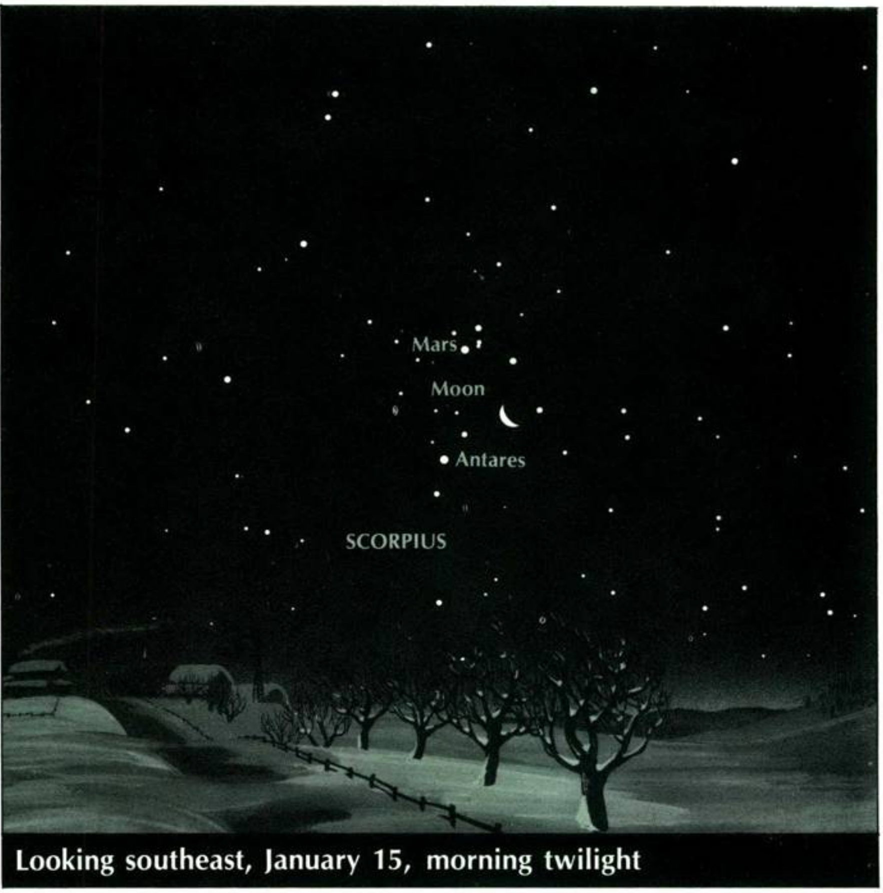
Eye on the Sky

Mercury Low in the Evening Sky

by Robert Burnham



Looking southeast, January 15, morning twilight

The Wanderers

No one wants to linger outdoors on a cold January evening, so you're lucky two of the three planetary "wanderers" visible this month are easy to find. **Venus** is the brightest. It's that brilliant "star" visible in the southwest roughly an hour after sunset. Venus has a magnitude of −4.0 and shines pure white; it sets two-and-a-half hours after the Sun does.

The other prominent planet is **Jupiter**, high in the south during evening twilight. At magnitude −2.4, Jupiter is about four times dimmer than Venus, but Jupiter is more eye-catching because of its commanding place in the southern sky. Jupiter brightens a dim region in Pisces roughly halfway between the Great Square of Pegasus (on the right) and the Pleiades (on the left). If you can, observe Jupiter in a telescope and look for four starlike satellites on both sides of the planet and the two parallel dusky bands crossing the disk. If you watch for an hour or more, you'll notice subtle shifts in the satellites' positions; you may even see different features on the disk of the planet.

January's third evening planet is **Mercury**. Mercury orbits close to the Sun, so it is visible only intermittently. (See the box on page 107 for the dates when it will be most visible.) In the first of its apparitions this year Mercury can be seen from about January 15 until February 5; best visibility lasts from greatest elongation on January 26 through the 30th.

Spotting Mercury is difficult this month, even when skies are clear: at best Mercury has only a third of Venus' elevation. Find a site with nothing blocking the view to the southwest. (In a pinch a rooftop will do, but take care — heavy clothing lessens your agility.) Forty-five minutes after sunset is a good time to look — the sky is mostly dark and Mercury hasn't yet sunk too low. Look to the lower right of Venus. (Binoculars will help.) Shining warm white, Mercury remains at magnitude −0.9 from the 15th to the 20th and then fades to magnitude 0.0 on the 31st. By February 5 it drops to magnitude 1.7.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

To see the other two naked-eye planets, go outside an hour before sunrise. **Mars** is prominent in the southeast, shining amber white at magnitude 1.4 among the stars of Libra and Scorpius. The star Antares lies nearby, its color and brightness closely matching those of Mars. You can tell them apart because Antares is slightly brighter and Mars moves relative to the surrounding stars. During the daytime on the 21st, Mars passes 5° to the north of Antares.

On January 1, **Saturn** is quite low and hard to see. But by the 15th, it has half of Mars' elevation and is relatively easy to spot. To the lower left of Mars, Saturn appears cream white in color and shines at magnitude 0.5.

The Starry Sky

January nights are usually cloudy over most of North America, but the clearing that follows a cold front brings skies so dark you can almost hear the stars sparkle. However, this kind of clearing leaves the atmosphere so unsettled that star images dance wildly in every telescope eyepiece. Believe it or not, these nights are better for naked-eye or binocular viewing.

Opposite page: On April 3, 1984, a day before greatest elongation and a day after New Moon, Mercury could be found low in the western sky. This month Mercury reaches greatest elongation (19°, the same as in 1984) on the 26th, and will again be visible low in the western sky. Photograph by Owen J. Thomsen, taken with a 190mm lens at f/22, ISO 400 film, and a 20-second exposure.

If you look up into the southern sky on an evening when the Moon rises late (between January 10 and 20, say), you immediately notice **Orion** the Hunter. His wasp-waisted figure with its three-starred belt and sword is almost as familiar as the Big Dipper. But as the map shows, Orion is more than just the oblong between Betelgeuse and Rigel. Take time also to trace Orion's upraised club and to identify the line of Pi (π) stars marking his shield.

Orion's belt stars point down and left to his faithful hound **Canis Major** (see Skylore), standing on stubby hind legs with a forepaw extended. Sirius, the dog's head, is the brightest star in the sky with a magnitude of −1.46. Sirius is one of the stars closest to us, lying at a distance of 8.7 light-years. Below Sirius is M41, a pretty star cluster in binoculars and small telescopes. Orion's other hound, **Canis Minor** the Lesser Dog, lies to the upper left of

January Night Sky

Full Moon
January 3
8:40 p.m. EST

Last Quarter
January 12
2:04 a.m. EST

New Moon
January 19
12:26 a.m. EST

First Quarter
January 25
4:53 p.m. EST

3rd The Moon is Full at 8:40 p.m. EST. The Quadrantid meteor shower is active late tonight and into the predawn hours of the 4th, but the Full Moon greatly diminishes the shower. Earth is at perihelion (closest approach to the Sun) around 7 p.m. EST: we are 0.983252 astronomical unit (147.1 million kilometers) away from the Sun.

7th The Moon is farthest from Earth at 12:54 a.m. EST: 252,265 miles (405,982 kilometers).

12th Last Quarter Moon occurs at 2:04 a.m. EST.

15th Mars lies north of the Moon in the predawn sky (see diagram on page 54).

17th The waning crescent Moon passes south of Saturn in the predawn sky.

19th The Moon is New at 12:26 a.m. EST and closest to Earth at 3:52 p.m. EST: 222,146 miles (357,509 kilometers).

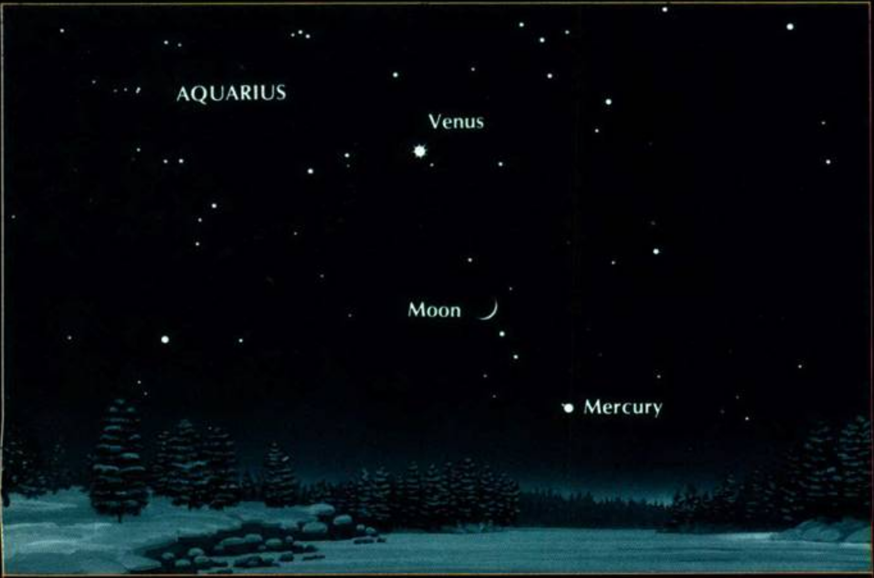
20th A very slender crescent Moon lies to the upper left of Mercury in the evening sky (see diagram below).

21st Mars passes 5° north of the star Antares in Scorpius during the day. In the evening sky Venus lies just to the lower right of the crescent Moon. (It is covered by the Moon for viewers in parts of South America and far western Africa.)

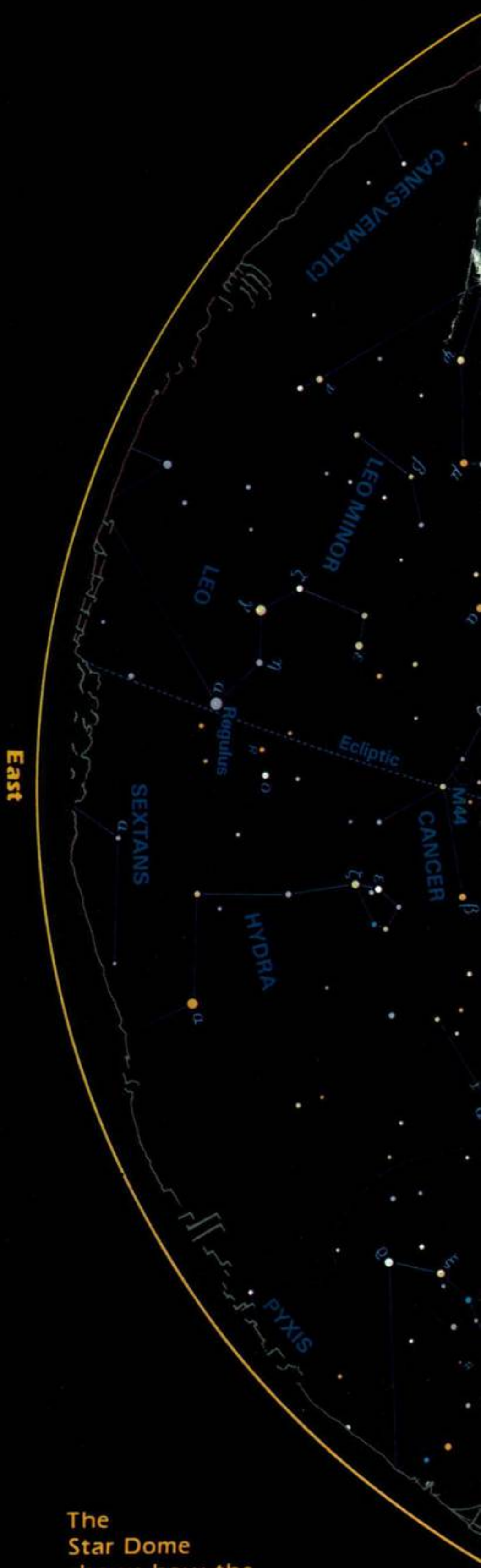
24th The Moon lies north of Jupiter in the evening sky.

25th First Quarter Moon is at 4:53 p.m. EST.

26th Mercury is at greatest elongation in the evening sky. It remains visible low in the southwest into early February.

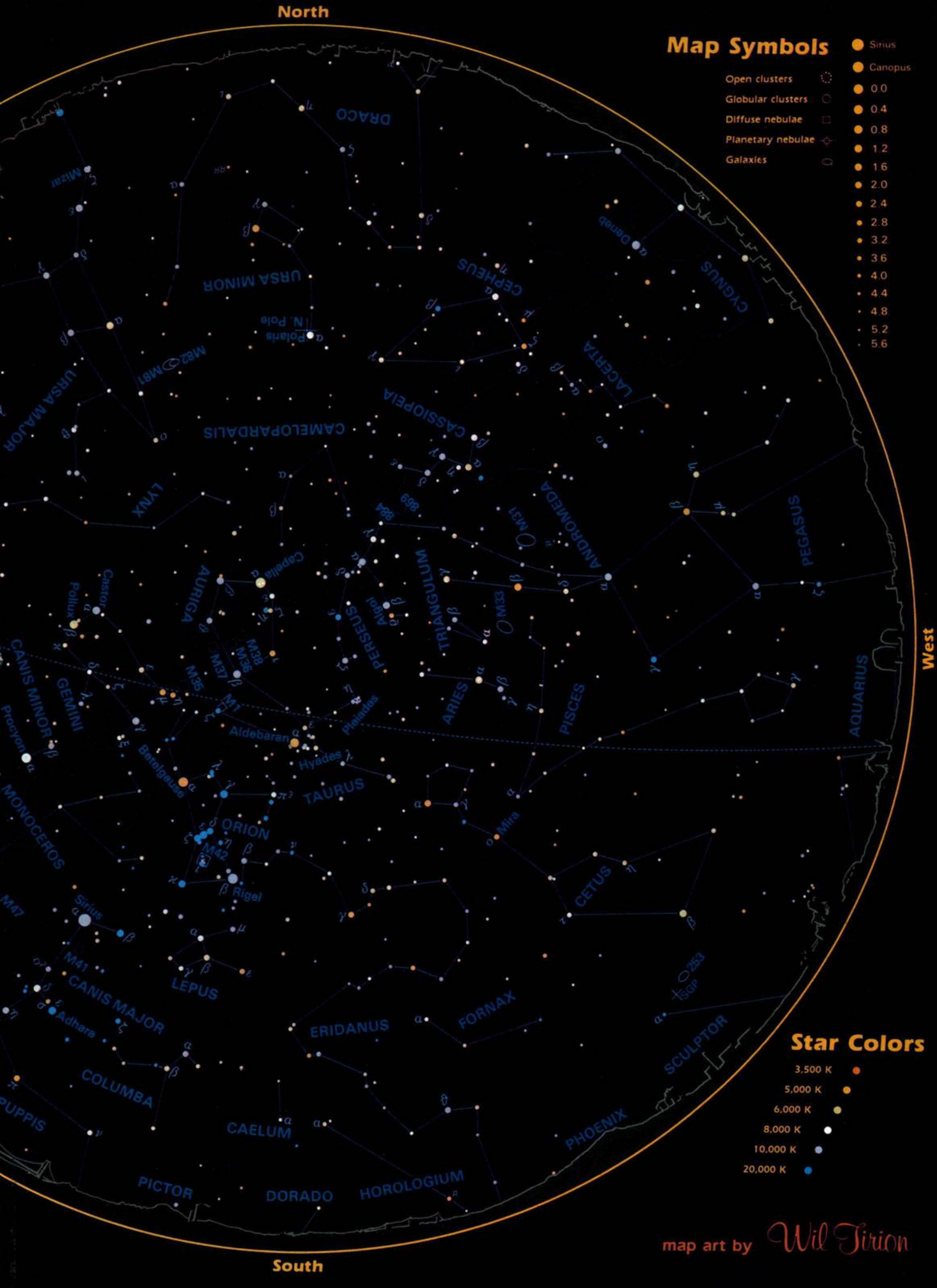


Looking southwest, January 20, evening twilight



The
Star Dome
shows how the
sky looks at:

10 p.m. on January 1
9 p.m. on January 15
8 p.m. on January 31


North
South
West
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
DRACO
URSA MINOR
N. Pole
Polaris
Mizar
M81
M82
URSA MAJOR
CAMELOPARDALIS
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LACERTA
CASSIOPEIA
LYNX
ANDROMEDA
M31
869
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M37
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CANIS MAJOR
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FORNAX
253
SGP
ERIDANUS
SCULPTOR
COLUMBA
PUPPIS
CAELUM
PHOENIX
PICTOR
DORADO
HOROLOGIUM

map art by Wil Tirion

Opposite page: Stars trace out their concentric diurnal paths in this extended exposure of the circumpolar region over Clocktower in the Wapiti Valley west of Cody, Wyoming. Photo by Dewey Vanderhoff.

Sirius, roughly level with Rigel; its chief star is creamy yellow Procyon, a name that means "before the dog," which refers to the fact that it rises before Sirius. Procyon, too, is a nearby star only 11 light-years distant.

Orion and his hounds push perpetually westward against **Taurus** the Bull. Its snorting, angry head is easy to see in the V-shape of the Hyades star cluster. First-magnitude Aldebaran — not a member of the cluster itself — is Taurus' eye, the Hyades form its muzzle, and two horns run eastward, one toward Zeta (ζ) Tauri, the other toward Beta (β) in Auriga. Above and west of the Hyades the more compact Pleiades cluster glitters compellingly in the dark, cold sky. The Pleiades look best at about 7x in binoculars.

Auriga's pentagon is easy to make out, though it doesn't much resemble a man driving a chariot. Its brightest star, zero-magnitude Capella, is the same color as the Sun (though it is classified as a yellow giant) and lies 42 light-years away. Follow Taurus' other horn past Zeta to **Gemini** the Twins, a long rectangular figure representing Castor and Pollux, twin heroes from Greek mythology.

When you trace the bright stars from Canis Major through Orion, Taurus, and Auriga, you are following the winter **Milky Way**. Onward from Auriga we pass the zenith and start to drop toward the northwest horizon. The next Milky Way figure is **Perseus** the rescuer of Andromeda, whose stars form a bent wishbone. Perseus has mostly 3rd-magnitude stars, but a sweep with binoculars reveals a great many fainter ones.

Following the Milky Way west of Perseus you encounter the Double Cluster (869 and 884 on the map). This pair of open clusters can be seen with the naked eye under a dark sky as two misty patches. But to really appreciate the clusters, use binoculars. The easternmost cluster, 869, is the brighter and richer of the two.

After passing the Double Cluster, we come to **Cassiopeia** the Queen, whose sharply angular figure is distinctive in the sky. Cassiopeia was the mother of **Andromeda**. The princess herself lies to the left of Cassiopeia (turn to face northwest) and forms a long "V" of stars that diverge from a star labeled Alpha (α), the star in the northeast corner of the Great Square of **Pegasus** the Flying Horse. Andromeda contains a galaxy similar to our own called M31, which is visible to the naked eye under good conditions.

Andromeda's nemesis, **Cetus** the Whale, lies well to the left beyond Jupiter, the bright planetary visitor in **Pisces** the Fishes. But Cetus claims our attention for another reason this month: the special star labeled Omicron (o). Several hundred years ago Omicron was named Mira (the Marvelous) because it changes brightness from about 3rd magnitude to about 9th magnitude over a period of roughly a year. Mira should be reaching its peak brightness around January 9. How bright does it seem to you?

Skylore

It's hard to imagine a hunter without a hound or two to scout his prey, and Orion is no exception. Canis Major is always depicted as a wiry and swift hunting dog, only half-tamed. On the other hand, Orion's second dog, Canis Minor, is a basic, shaggy, house mutt — not immune to a good chase but with a wide streak of easygoing laziness.

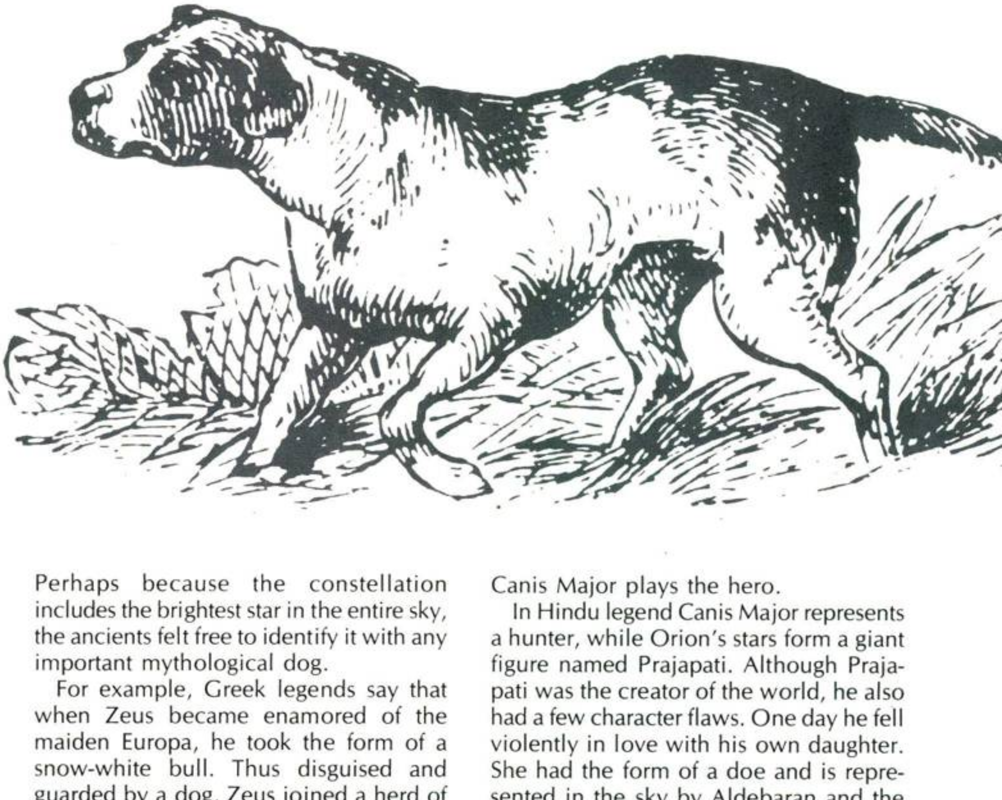
You would expect Orion and Canis Major to be indivisibly linked. Yet, surprisingly, Canis Major has often led a mythological life independent of Orion's. Perhaps because the constellation includes the brightest star in the entire sky, the ancients felt free to identify it with any important mythological dog.

For example, Greek legends say that when Zeus became enamored of the maiden Europa, he took the form of a snow-white bull. Thus disguised and guarded by a dog, Zeus joined a herd of cattle grazing near the seashore where Europa was walking. Impressed by the bull's gentle nature, Europa played with him and eventually climbed on his back. Zeus then dove into the ocean and swam strongly away, carrying the lass off to his hide-out. Mythmakers point to this story to explain an undying enmity between Canis Major and Taurus the Bull.

Canis Major was also identified with Laelaps, a dog that figures in two separate stories. In the first, Laelaps was one of many hounds owned by Actaeon, a hunter who had the bad luck to accidentally see the goddess Artemis while she was bathing in a stream. Enraged, she changed him into a stag and set his pack of dogs on him. Actaeon ran swiftly, but eventually the pack, led by Laelaps, caught up and tore him to pieces.

In the other legend Laelaps was the hunting dog given (along with a spear that never missed) to Cephalus when he married the beautiful Procris. Soon after the marriage Cephalus went on a hunting trip, leaving Procris behind. Deciding to surprise him, she set out alone for his camp and reached it long after nightfall. Ever alert, Laelaps stirred and growled gently to let Cephalus know something was nearby. Cephalus leapt up, seized the magic spear, and hurled it into the dark, killing Procris. In grief Cephalus turned on the hapless Laelaps and set him in the stars, where he is doomed to chase the celestial Hare Lepus forever.

In these legends the dog is the catalyst, the element that sets the events on course for their usually tragic outcome. It's nice therefore to finish with a story in which Canis Major plays the hero.



In Hindu legend Canis Major represents a hunter, while Orion's stars form a giant figure named Prajapati. Although Prajapati was the creator of the world, he also had a few character flaws. One day he fell violently in love with his own daughter. She had the form of a doe and is represented in the sky by Aldebaran and the Hyades.

Frightened out of her wits, she escaped by running blindly away. Changing himself into a stag, Prajapati set off across fields and woods in wild, lustful pursuit. He had almost caught her when a hunter shot him near the heart with a special arrow. Mortally wounded, Prajapati was pinned to the sky.

If you go out on any winter night, you can clearly see all three figures visible in the south. The hunter, the daughter, and the lustful Prajapati with a three-starred arrow stuck in his middle.

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Gazer's Gazette

Confessions of an Eclipse Addict

by Joel K. Harris

I have a confession to make. I am a solar eclipse addict. The thought of seeing the Sun disappear in a clear sky in the middle of the day for a few brief minutes makes the blood race in my veins. In fact, the only time I feel really alive is when I am standing in the shadow of our natural satellite. For better or worse, I'm hooked.

Oh, I enjoy the conventional phases of astronomy. Deep-sky objects are inspiring, and a good view of the planets is impressive and fascinating. Yet even though I've had a total of seven "fixes" in fourteen years, I cannot seem to get enough of what I believe is the most impressive event people can witness on Earth.

Every eclipse is different, which adds immensely to the pleasure of viewing these events. I am still awestruck by the variation of phenomena that is visible. The shape of the corona, for example, varies according to a 22-year cycle, which is linked to sunspot activity. In active years the corona is almost circular with various "petals" reaching out from the dark disk of the Moon. In less active years huge streamers emanate from the Sun's equatorial regions. At these times of minimum activity, delicate, wispy polar brushes are visible at the north and south poles of the Sun. Sometimes bubbles or other strange shapes are visible in the corona.

Adding to the compelling beauty of an eclipse are prominences, bright, pink projections emanating from the limb of the eclipsed Sun. These eruptions of gas are many times larger than Earth and resemble slow-motion terrestrial fountains, except that they're different in color and size. During the few minutes of totality these prominences change shapes very slowly (or not at all), but that's because they are 150 million kilometers distant.

Everything else aside, my fascination with "eclipse chasing" has taken me to parts of the world I might never have explored had the Moon's shadow not been passing over that particular piece of real estate. Kenya, New Caledonia, Mauritania, Senegal, Indonesia — this sounds more like the travelogue of a globe-trotting journalist than the itinerary of an astronomer!

Expensive? Yes, relatively. That is, if you are comparing an eclipse tour to two weeks in Hawaii or the Bahamas. But you can travel to Hawaii or the Bahamas anytime. An eclipse is special.

The next total eclipse occurs on March 18, 1988. One of the two countries that the eclipse path will cross is the Philippines, specifically the island of Mindinao in the southern part of the archipelago. Civil unrest and rebel uprisings there have reached unprecedented levels and caused the U.S. State Department to issue a traveler's advisory to stay away from the area — or risk possible abduction or bodily injury.

Fortunately the other nation in the path of totality is Indonesia, a country that held its five-year national elections last April. This country provides a tenfold more stable political environment in which to see the eclipse.

Plan Ahead for an Eclipse

Obviously if you decide to join an eclipse tour, there are a number of factors to consider, not the least of which is your ultimate destination. Just where in the world are you going? The type of clothing you should bring, the need for a passport or a birth certificate, the kind of inoculations required, the amount of money you should bring — all these details are determined primarily by the region you will be visiting. Naturally these conditions will vary, so take your tour guide's suggestions about what necessities you should bring. In addition, pay close attention to airline baggage restrictions —usually two bags per person are allowed, and these are limited by size. There are also weight restrictions in some sectors outside North America.

If the details concerning your destination seem in order and you don't foresee yourself flying into a military coup somewhere, you can begin thinking about what observing activities you want to do during totality. Will you be going along just to enjoy the show with the naked eye, or will you want to observe with binoculars or a telescope? Will you want to photograph the event or sketch it? Perhaps you will want to make an audio or a video tape of the eclipse.

Many veteran eclipse observers call totality the fastest three minutes (or two minutes, or whatever you have) of your life. It's true! The time will seem to fly. With all of the observing activities you can do and a limited time in which to do them, organizing your activities makes sense.

Write down what you want to do and then divide up the duration of totality among these activities. If you find you can't possibly do everything on your list, get rid of some of the activities. This may seem difficult, but you will be better off if you make these decisions beforehand rather than during the frantic few minutes of totality.

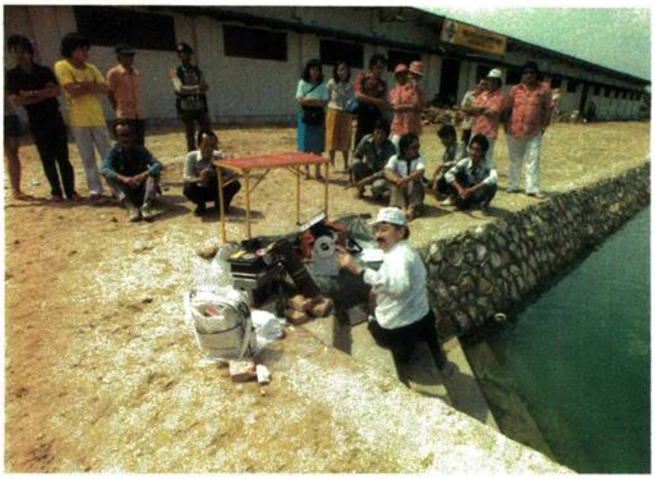
Lay out the equipment you want to bring (cameras, tripod, lenses, filters, telescopes, etc.) and decide if you can carry all of it comfortably in one hand and or under one arm (or in your backpack). If the answer is no, leave some of it behind. Carrying fifty pounds of eclipse gear 10,000 miles from home through four or five cities before the eclipse occurs gets pretty tiring!

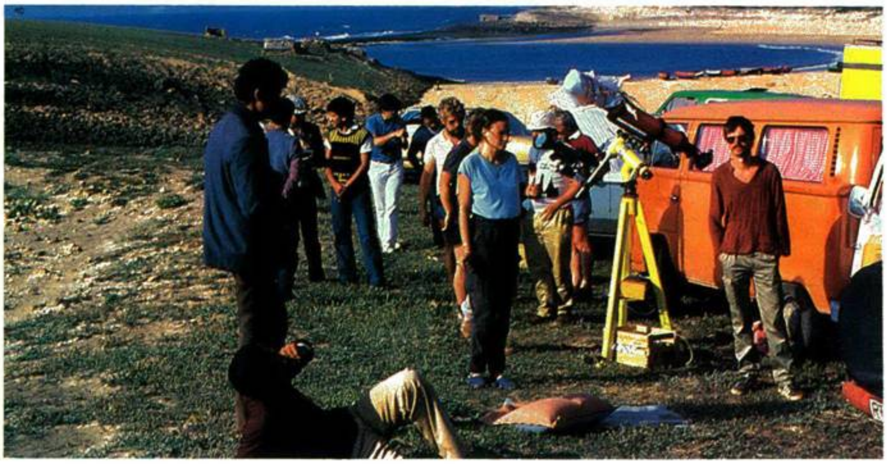
If you plan on photographing the eclipse, get familiar with the equipment you will be using during totality. I learned how important this can be the hard way in 1983 in Indonesia. I borrowed a Schmidt-Cassegrain telescope and adapted my 35mm SLR camera to photograph through it. Ten seconds into the total phase of the eclipse the camera and adaptor fell off the scope and my photographic plans were ruined.

I learned another lesson the hard way in Kenya in 1980. I had purchased an electric film winder for my camera and was a bit too eager to try it out for the eclipse. Even though I had a thirty-six-exposure roll of film at the start of totality, I used all but five exposures during the first minute of the eclipse. An audio tape I made of the

Top: Daylight becomes twilight during the total phase of a solar eclipse. Photo of the June 11, 1983, eclipse in Yogyakarta, Indonesia, by William P. Sterne, Jr.

Above: Pink prominences rim the limb of the eclipsed Sun in this photograph by Jacques Guertin of the February 26, 1979, eclipse, which was visible in Canada and the northern United States.





Above: Ten minutes before totality, Richard Berry prepares for umbral passage during the June 11, 1983, eclipse in Tuban, Indonesia. About twelve minutes later (above right) the Moon's umbra brings a dusklike darkness to the observing site. Photos by Eleanor Berry.

Right: Members of the European eclipse expeditions relax on the beach near Sidi Moussa, Morocco, before the June 20, 1984, annular eclipse. Photo by Ed Leikam.

Opposite page: Jim Rouse combined three frames taken during the February 26, 1979, eclipse to illustrate the diamond ring, prominences, and Baily's Beads.

event distinctly recorded my unprintable reaction when I realized I had only four exposures to last me through totality!

Practice the observing program you want to follow several times *before* you go on the trip. The length of totality is known beforehand and is usually mentioned in advertisements for the tour, so it is a simple matter to make practice runs at home, timing yourself so you can pace your observing activities precisely. You may want to make a series of telephoto shots to capture prominences and the corona, or maybe you would rather concentrate on wide-angle sky exposures with a few photos of the site thrown in for good measure. Many industrious observers take along two or three cameras.

If you are unable to do all the things you want to during totality, trim your agenda. If during your practice runs you find you are rushing or are fearful of a time squeeze, cut back somewhere. The frenzy isn't worth it.

Do you think you have your program down to a science and that it is perfectly timed? Good. Try it in an almost totally dark room and see if it goes as smoothly as you expected. If so, then all you have to concentrate on is fine tuning. If your program takes longer in the dark, however, cut your activities again until you finish on time. Think about minor emergencies like this: your tripod gets knocked out of position or your camera winder freezes up. It's easy for things to go right in a dark room thousands of miles and months away from the eclipse. It's only during totality that tiny set screws fall into the sand, shutter cables jam, and power cords fail to work.

But let's face it: A disaster could happen. What then? Don't fight it. After I had the camera-adaptor failure in 1983, I thought about trying to repair the problem for about fifteen seconds. I then realized how dumb the idea was, so I grabbed my binoculars and just enjoyed the show. Granted, I had four prior eclipse experiences to train me not to try a repair job, but it is fairly easy to get carried away and lose control when your best plan falls apart. As Arthur Dent is always being told in the *Hitchhiker's Guide to the Galaxy*: "Don't panic!" After all, you can still observe with binoculars or your unaided eyes. In fact, you may well enjoy the eclipse more than those who are fussing with cameras, film, and telescopes.

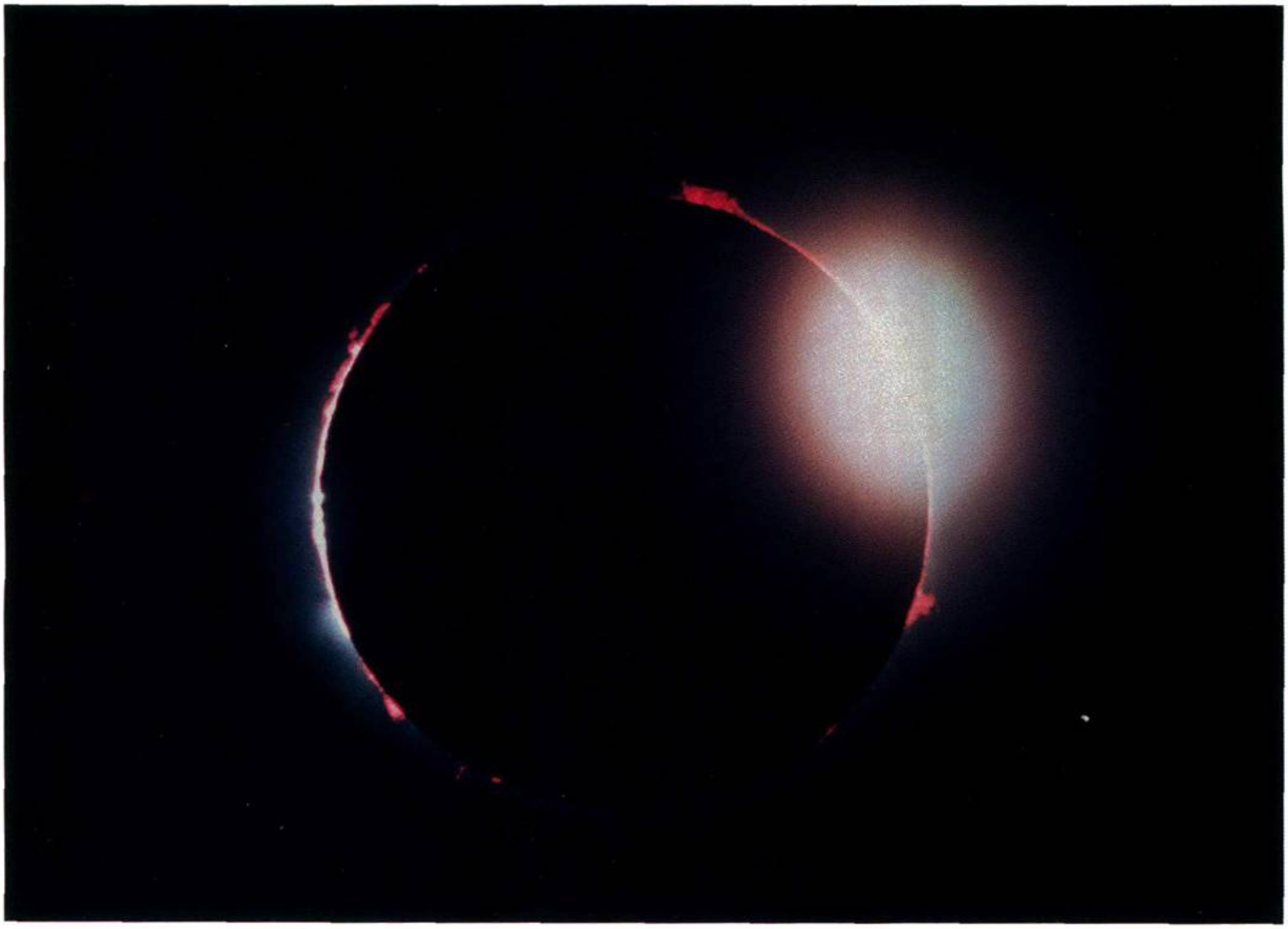
The Eclipse Experience

What is it like to witness an eclipse, to actually be there? If you have a telescope or a camera system, you begin looking for the first contact of the Moon's limb with the Sun's limb using over-the-aperture solar filters. These filters remain on until just seconds before totality, when it is safe to view and photograph the Sun without the use of filters.

At first you see the bright disk speckled with sunspots. Then a tiny notch suddenly appears at the western limb of the Sun, and over the following hour to hour and a half the silhouette of the Moon slowly, almost agonizingly, makes its way across the solar disk. Still, during this initial phase of the eclipse the overall ground conditions of temperature, light, and scenery don't change significantly. Even when 75 percent of the Sun is covered by the Moon, it's not evident that something big is about to occur.

If you are not within the relatively narrow path of totality (usually one hundred to two hundred miles in width), the sky show is not that good. It never gets very dark and, compared with totality, it's not that exciting. However, if you are in the total eclipse path, the next thirty minutes could be among the most thrilling of your life!

With half an hour to go until totality, something strange happens. Are your eyes going haywire, or is the light turning a mustard or amber shade? As the sunlight diminishes, the Sun acts like a point source of light, not a diffuse, highly distant light source. Shadows become extremely sharp — even for objects a meter or more above the ground. If you have rather long hair, you can discern the shadows of individual strands on the



ground. The air starts to get cooler, especially on a warm day in the tropics (or in the dead of winter in Canada). People experience what is called an "eclipse wind" or breeze as the Moon's approaching shadow cools the atmosphere. If there are animals nearby, they start to act as if night were about to fall — and their instincts are correct, it is. Birds look for a roost; some birds change their songs to an evening tune.

Maybe the most fascinating creatures to watch are those who call themselves masters of this planet — humans. Even though this is the late twentieth century and man has reached out into space, people still get confused and disoriented at an eclipse. With the sunlight fading, our minds tell us this is only because the Moon is covering the Sun; it's an event that has been predicted years in advance. Yet something very deep and old inside all of us is stirred, touching ancient drives.

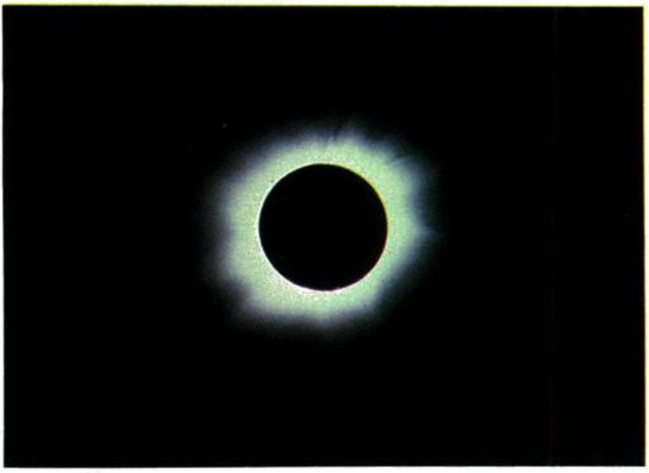
Five minutes before totality it is now like twilight. Still light out but just barely. The bright planets are visible, especially Venus, Jupiter, and Saturn if they are in the sky. What looks like a thunderstorm approaches from the southwest. But this is no storm. What you are seeing is the lunar shadow racing over the surface of the Earth at more than 1,500 miles per hour, ready to engulf you. About this time people occasionally report seeing something known as "shadow bands," bands of parallel dark waves that race across the land just prior to totality. While not perfectly understood, these bands are thought to be caused by the bending of the final traces of bright sunlight by the various layers of Earth's atmosphere. The effect is not unlike the bright patches of sunlight on the bottom of swimming pools. Sometimes shadow bands are easily visible; many times they elude detection.

When you look at the Sun, the last events heralding second contact unfold. Just before totality the rough, uneven limb of the Moon snuffs out all but a few bright ovals on the solar photosphere (surface). These spots of light streaming through the lunar valleys are called Baily's Beads, in honor of the English astronomer Sir Francis Baily, who studied them during eclipses in the early 1800s. As these spots become visible you hear veteran eclipse watchers call out "Baily's Beads — filters off!" Now is the moment to watch the eclipse with the naked eye. There is no danger of eye damage at this time, because the bright light of the Sun's surface is blotted out by the Moon. If you have binoculars or a telescope, you see a red arc appear where you earlier viewed Baily's Beads. This is the Sun's chromosphere, an upper layer of the Sun invisible to us normally because the brighter solar surface drowns it from view.

Then like a dormant flower exploding into blossom the Sun's corona — its outermost atmosphere — bursts into view. It is an indescribable sight, completely alien, and one that totally rivets you to the here and now. Suddenly the day is completely still — as in the eye of a hurricane — and your senses seem more attuned to your surroundings. Clock drives and film winders whir around you in mechanical synchronization. The quiet viewing field is punctuated with an occasional hoot or shout of joy. Some observers weep; others chuckle to themselves.

The Sun is now a black disk in the sky. For a brief moment you can almost feel the motions of the Earth and Moon grinding on as they have for billions of years. Earth is the only place in the solar system where an eclipse looks like this, because the Sun and Moon have virtually the same apparent diameter, even though the Sun is four hundred times more distant than the Moon. I wonder if it is any accident the Earth-Moon-Sun geometry is so perfect that it sets up the eclipse spectacle for sentient beings to appreciate.

Amidst this riveting show, try breaking away from the scene above your head and just look around slowly at the whole horizon. In the southwest and northeast (the line along which the eclipse is traveling) the dark lunar umbra, or shadow, reaches the horizon. In a direction perpendicular



Above left: The feathery outer extensions of the corona can be seen in this photo taken by Joel Harris during totality at the February 16, 1980, eclipse in Kenya.

Above right: A group of photographers and observers on the upper deck of the cruise ship *Cap Des Pins* await totality during the November 22, 1984, eclipse in the Coral Sea, one hundred nautical miles southwest of Noumea, New Caledonia. Photo by James Manning.

Right: The eerie, dusky blue umbral shadow in the sky looks like an approaching thunderstorm. The shadow moves across the Earth at more than 1,500 miles per hour. Photo by Laura Woodard taken during the February 26, 1979, eclipse.

to the shadow path that amber light you saw before totality delineates the northern and southern limits of the eclipse path (outside of which one sees a partial eclipse).

Now the total phase of the eclipse is almost complete. Yet one final jewel awaits. Just prior to third contact (the official end of totality) one or two especially deep lunar valleys on the west limb of the Moon may allow some of the Sun's light to reach us. (This phenomenon may also occur prior to totality, or second contact, when a conspicuous Baily's Bead flashes briefly from the Moon's limb.) The burst of bright light usually washes out all but the innermost part of the corona. What is left is a thin coronal ring and a single (or double) "diamond" of searing light. Fittingly this phenomenon is called the "diamond ring effect." It is very common to hear great cheering and applause when the diamond ring appears — as if we are saluting some extraterrestrial work of art. In fact, that is exactly what we are doing.

From the point of third contact on, the remainder of the eclipse seems anticlimactic. Some diehard purists replace their solar filters on their cameras or telescopes and savor the death throes of the final partial phases. But by then most people wander around the viewing site in pleasurable shock or cluster into little groups, exchanging personal interpretations of what has happened. Many folks stand in one place grinning blissfully. The eclipse is over, but not the pleasure of having seen it. That lasts a lifetime.

Strategies for Successful Viewing

Naturally, to observe an eclipse you need clear skies, but we all know how unpredictable the weather can be. So what do you do if clouds spoil the eclipse? The best advice is to just accept your fate and make the best of your trip. You can't fight the weather.

Nevertheless, barring a solidly overcast sky or a rain squall, there is still a lot to see. Look at the changing colors of the clouds as the shadow approaches and recedes. See if you detect an eclipse wind. If the clouds are scattered and there are patches of clear sky between them, you may catch a glimpse of the corona or chromosphere.

But if you want to increase the odds of viewing under a clear sky, there are a couple of things you can do. Without a doubt one of your best advantages is being mobile. It is likely going to be clear *somewhere* in the eclipse path, and if the sky clouds up at one site, there's a chance you could make it to a clear site in time providing you can pack your equipment quickly and go.

Of course mobility will vary depending on your site and your mode of transportation. I have viewed eclipses from land, sea, and air and prefer land-based observing sites. Besides providing the most stable viewing, it is easy enough to chase the eclipse on land by hopping into the bus or four-wheel drive vehicle and driving to a new location. A ship is somewhat mobile, but it constantly rolls on the ocean. Still you are outdoors on a ship and can appreciate the changing environment as totality approaches.

This can't be done when viewing from an airplane. Inside the pressurized cabin you don't experience the changes in the environment: there is no eclipse wind and the temperature remains constant. The "viewability" often depends on the air turbulence and optical quality of the windows. Viewing a solar eclipse from an airplane reminds me of watching a movie of an eclipse rather than being there.

In addition to increasing your own chances for viewing the eclipse, you can also better the odds for everyone at your eclipse site by adhering to proper eclipse etiquette. (Yes, such a thing exists!) For example, don't become so overwhelmed during totality that you knock over other people's hardware. Of course you can be excited, but make it "controlled enthusiasm." If you feel you need a light source to see your camera or telescope during totality, use a red-filtered penlight or flashlight. White lights will disrupt other observers and possibly even ruin their

Some Questions to Ask about Eclipse Tours

With all the variable social and political climates in the world, it's unwise to travel on your own to an unfamiliar country to view an eclipse. Eclipse tours, however, are the easiest way to go because someone else worries about finding the site, getting through customs, locating suitable hotels, and finding local transportation.

Suppose you decide to join an eclipse tour. What considerations do you have to weigh? First, before thinking about what to wear or bring, you must do your fair share of homework by investigating the tour company you are thinking about selecting. Contact the various tour companies and request information on their eclipse expeditions. (For a list of tour companies see "Travel and Tours" in the Equipment Directory of the October 1987 issue of ASTRONOMY.) Those companies offering eclipse tours will send you a packet containing everything from a schedule of events to general information about the trips.

After you have studied this material, contact the tour companies that look promising and ask lots of questions. Have they conducted tours of this type before? What is their track record (have they been clouded out in the past)? Is the tour leader an astronomer or a person knowledgeable about eclipses? Has there been a site survey conducted, and if so, when? Is there a reserved, dedicated observing area for the tour group? Is ground transportation provided to and from the site?

Though the eclipse is the main attraction, the event will take up one day of your time at most. What other activities, if any, have been arranged for the tour? Are any sightseeing plans made? If so, where? What about scheduling?

Finally, what features does the tour price include? Most tour companies spell these out clearly in their literature. Make sure you know exactly what these features are and that there are no hidden charges. Basically the tour price should include ground transfers between airports and hotels (or between the airport and the ship if you are traveling by sea), meals and lodging, luggage conveyance, domestic flights within the country, and sightseeing costs.

Don't be afraid to be nosy about costs, luggage restrictions, deposits, and cancellation policies. When you're traveling halfway around the world, these are no small matters to consider. A pointed question asked before you pay your deposit might save you lots of disappointment later on. — *Joel K. Harris*

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photographs. And never take any photos with a strobe or flashbulb. (Incredibly, there's always someone who does this, spoiling other observers' eclipse photos.) A bit of common sense will serve you and everyone in your party.

Photographic Tips

It stands to reason that if you travel thousands of miles to view an eclipse, you will probably want to photograph the event, preferably with your own camera. Shooting an eclipse is not beyond the capabilities of anyone with a single lens reflex camera or, for that matter, an Instamatic. Your first consideration is how big an image of the Sun you want on film. Naturally the image size varies, depending on the focal length of the lens you use. Even a hand-held beginner's camera can capture something of the eclipse, though the Sun's image is so small you need a magnifying glass to see it clearly.

A quick and dirty rule of thumb to predict the size of the Sun's image on the photo is to divide the focal length of your camera lens by 115. The resulting number is the size of the Sun's image expressed in millimeters. For example, a 500mm telephoto lens divided by 115 equals a 4.3mm image size. An 11" by 14" print made from this negative would yield a solar disk that's just over two inches across and a corona that's about six inches across. A 50mm wide-angle lens divided by 115 equals 0.4mm — rather dinky even if you get a huge blowup made. To get a bigger solar image, use a longer focal length lens. An ideal range of size for lenses used with a 35mm camera is 500mm to 3000mm (the latter will probably be with either a spotting telescope or a standard scope with a camera adaptor). This range allows you to get the entire solar disk in the field of view and to photograph such details as solar prominences, Baily's Beads, the diamond-ring effect, and subtle coronal structure.

What about exposure? Fortunately eclipses are very forgiving photographically. The longer you expose during totality, the more you see of the corona (until the Earth's rotation causes the image to move, or the bright sky fogs the film). Two good reference articles on this subject are "Film the Eclipse!" by Richard Berry (Photography in Astronomy, November 1978) and "Photographing Our Nearest Star" by Rick Dilsizian (Photography in Astronomy, May 1987). Both these articles give rather detailed, technical guidelines for exposure times and film speeds, depending on what phenomenon you want to photograph.

To insure that your photos are properly processed and handled, begin every roll of eclipse pictures with a full-frame scenic photo to show the processing lab where to cut the film. Ask the film lab to hand cut your negatives or slides. This prevents automated developing equipment from slicing your eclipse photos down the middle should the frame counter be incorrectly set. And avoid having your exposed eclipse film rolls x-rayed at the airport. Despite assurances from security personnel, film retains and builds up x-ray dosages that can ruin your photos.

The four most critical points to remember about eclipse photography are to bracket your exposures (vary the exposure lengths), firmly anchor your tripod to lessen motion from film winding and shutter action, and wait a few seconds for all vibrations to diminish before opening the shutter for your next photo.

The fourth point? Never look through your unfiltered camera, telescope, finder scope, or binoculars at the partially eclipsed Sun! Even when the eclipse is 98 percent total, a lot of heat can reach your eyes. You won't notice it because the Sun is much dimmer, which is due to the encroaching Moon, and your eyes won't reflexively blink because the blinding white light of the Sun's surface is significantly reduced. Always use a safe solar filter to look at partial eclipse phases. Safe filters can be obtained through many astronomical supply houses, telescope manufacturers, and some astronomy clubs. Contrary to what you may have heard, smoked glass, overexposed film, neutral density photographic filters, and sunglasses are unsafe.

Three additional photo hints may mean the difference between success and disappointment. Before taking your eclipse pictures, recheck and tighten any and all set screws, nuts, and bolts on camera adaptors, tripods, or other hardware (airplanes and bumpy roads conspire to loosen screws and nuts). Next, open your camera iris to its fullest setting and move the focus to infinity. Use electrical or gaffer's tape to anchor these settings so they won't come loose during totality. Finally, place a fresh, full roll of film in each camera *prior* to totality. Do not attempt to change rolls during the eclipse — this will only cause panic and problems.

Once more, if your photos don't come out, or if you experience equipment problems and fail to take even one picture, don't despair! Others at the eclipse will take photos, and they will be only too happy to share them with you.

If you see just one total solar eclipse in your lifetime, I can guarantee you will become "hooked" just as I did. There's no going back. It changes the way you think about our place in the solar system and the universe; it changes your life. It surely changed mine!

Joel K. Harris is the former project information coordinator for the Galileo *Project at the Jet Propulsion Laboratory in Pasadena, California. He is now director of Twilight Tours, an astronomical/adventure tour wholesaler in Burbank. Harris is leading his fourth eclipse tour — to Indonesia — in March 1988.*

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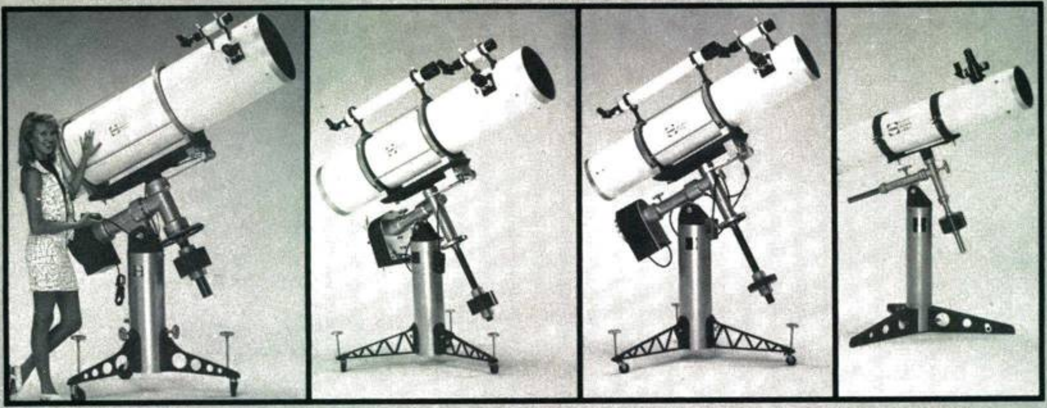

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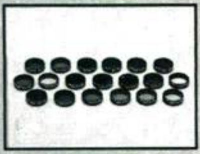

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Photography
in
Astronomy

High-Resolution Lunar and Planetary Photography

by Rick Dilsizian

Beginning astrophotographers almost always try to photograph the nearby members of our solar system first. But how many people are really happy with their initial results? More often than not these first astrophotographic experiences are disappointments.

Fortunately it doesn't have to be this way. I have discovered that successful lunar and planetary photographs hinge on nine key elements. By paying careful attention to each of these, you will be able to record intricate structure in Jupiter's atmosphere, dark markings on the surface of Mars, and tiny craters pockmarking the lunar surface.

What Is Eyepiece Projection?

Eyepiece projection is the best technique for making high-resolution photos of the Moon and planets. The process is actually quite simple: with a camera attached to a special adaptor on the back of your telescope, you carefully aim, focus, and shoot pictures.

The problem, in a nutshell, is that these objects appear quite small in the sky. Thus, in images taken with your telescope acting as the camera lens, the planets are just too small. Even the Moon's image is often less than an inch high, and planetary images are at least thirty to fifty times *smaller* than that. In eyepiece-projection photography an eyepiece magnifies the image formed by the telescope so it is large enough to show fine detail.

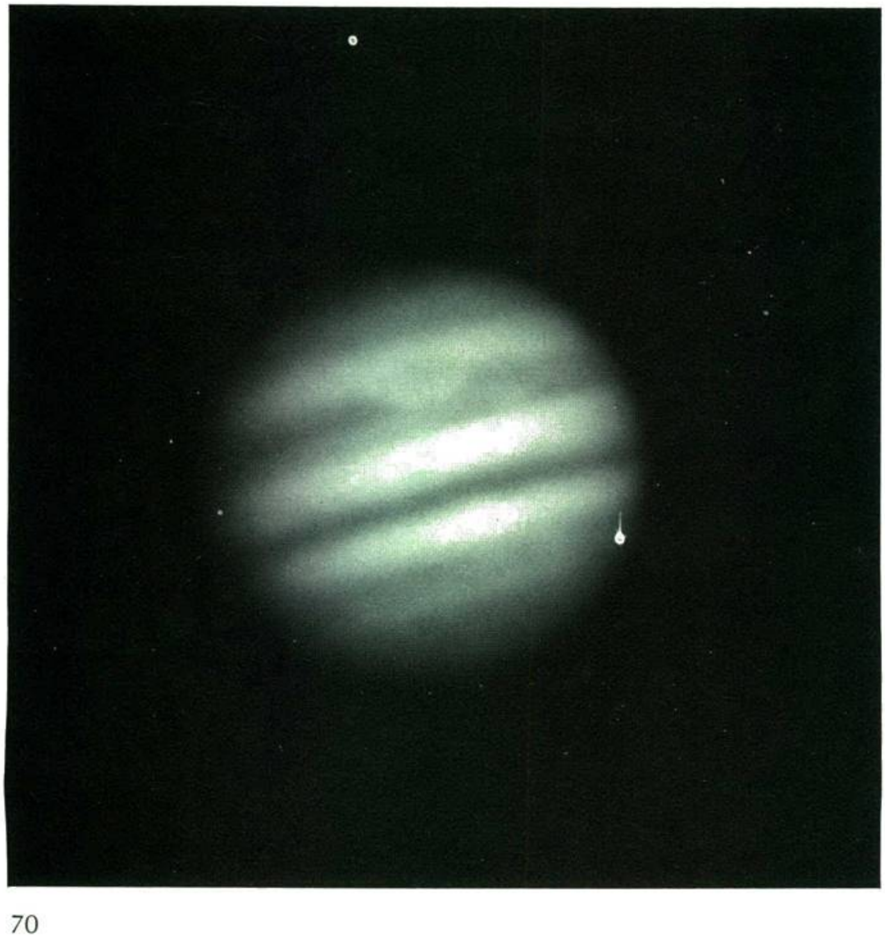
Eyepiece projection affords the best quality in high-resolution astrophotography because it produces big images. This is because magnifying the image formed by the telescope gives you a long effective focal length for your system. And the longer the effective focal length, the larger the image of the Moon or planet will be on the negative or slide.

It's analogous to taking photographs at the zoo. Who will get a better close-up of the lion in his cage: you with a normal 50mm lens or your friend with his 200mm telephoto lens? Your friend, of course. The image on his film is four times larger than that on yours because his telephoto lens has a focal length four times longer than your normal lens.

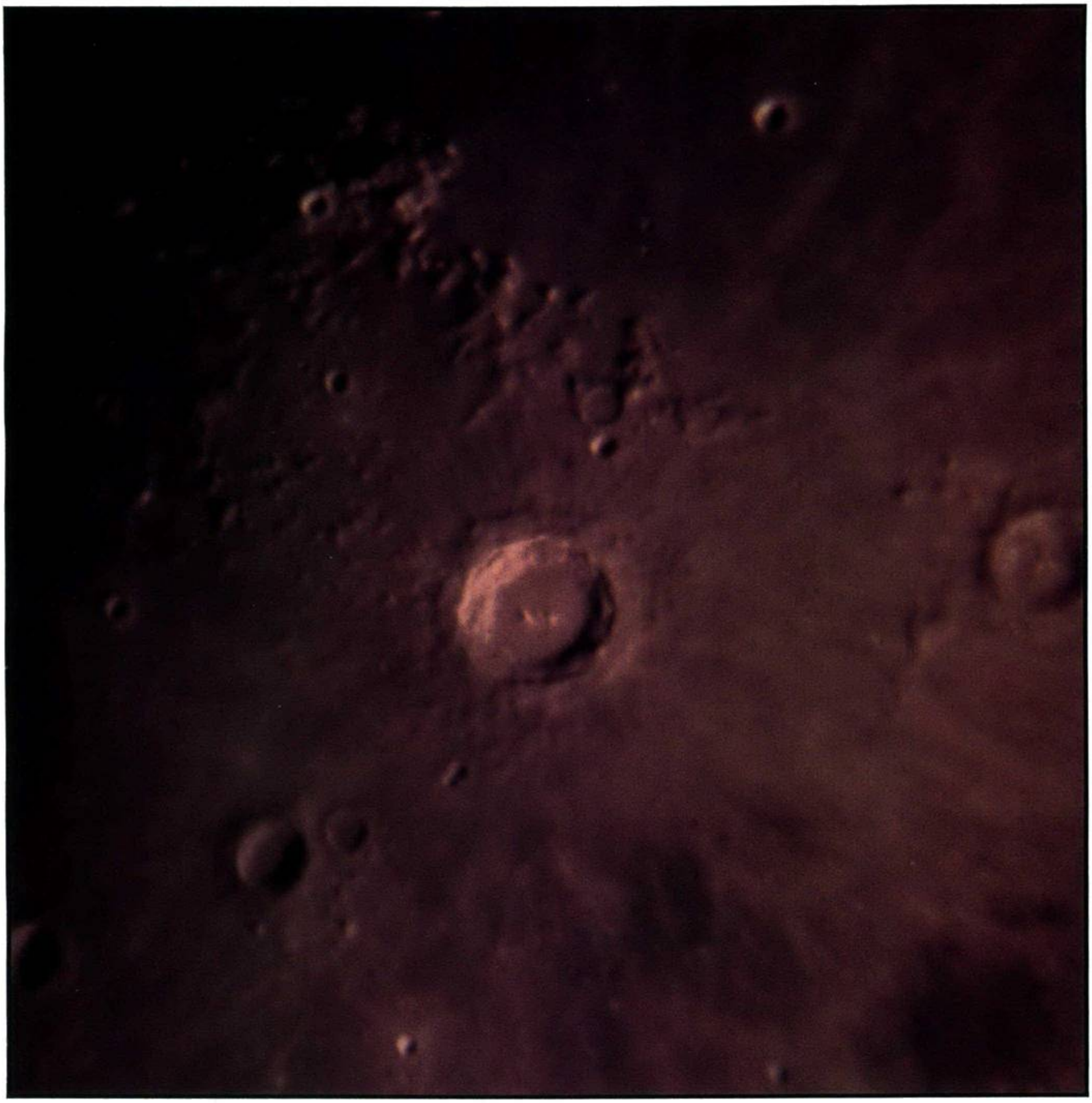
An effective focal length of at least 20,000 millimeters is usually needed to give reasonably large planetary images. This means the focal ratio of your system will be at least f/90 to f/110. Effective focal ratios in lunar photography will vary depending on what detail you want to bring out. Focal ratios of about f/40 are good for showing relatively large areas of the Moon's surface, while focal ratios of f/110 and higher are generally used to zero in on individual craters and other small features.

Necessary Equipment

The equipment you need for eyepiece-projection photography is readily available from telescope manufacturers, camera stores, and independent dealers. Fortunately you probably already own a telescope and camera, by far the most expensive pieces of equipment required.



Left: Jupiter, the largest planet in our solar system, offers a wealth of atmospheric detail for planetary photographers. Rick Dilsizian captured Jupiter and its Great Red Spot with a 14-inch SCT at an effective focal ratio of f/105 using eyepiece projection. This is a 2-second exposure on Kodak Technical Pan 2415 film.



Above: The constantly changing illumination of the Moon's surface provides astrophotographers with a variety of interesting targets. The crater Copernicus and its surrounding region are the subject of Rick Dilsizian's 4-second exposure on Kodachrome 64 film. Dilsizian used a 14-inch SCT operating at an effective focal ratio of f/80.

Starting at the telescope end, your scope should have a clock drive to compensate for Earth's rotation. In addition for an SCT you will need the "visual back" of the telescope — the part that attaches to the telescope and holds the eyepiece in place. You will also need a high-quality eyepiece to magnify the telescope image.

Next are the two pieces of equipment that will join the telescope to the camera. First is a "tele-extender" or camera adaptor — a long, narrow tube through which the image formed by the eyepiece is projected to the focal plane of the camera. From there a T-ring attaches the camera and tele-extender.

The camera forms the back end of the photographic system. It should be a 35mm single lens reflex (SLR) camera and have a detachable lens, because the telescope's optics will serve as the camera's lens system. Finally, a long cable release, preferably activated by air pressure, should be used to control the beginning and end of each photographic exposure to prevent unnecessary vibrations.

The actual setup and use of eyepiece-projection equipment is explained in this month's Equipment Atlas, "Tools for the Astrophotographer" by Richard Talcott on page 78. When the camera is attached to the back end of the telescope, the telescope's weight distribution is altered substantially. To properly balance the telescope, you will need to adjust the counterweights. This will also insure the smooth operation of the telescope's clock drive. By practicing this routine ahead of time, you will save yourself a lot of time and effort out under the stars.

Nine Factors for Success

I have found that successful eyepiece-projection astrophotography depends on nine key factors:

- Good optics: your pictures will be no sharper than the image formed by your telescope.
- Appropriate film: an extraordinary image will appear ordinary if it is recorded on ordinary film.

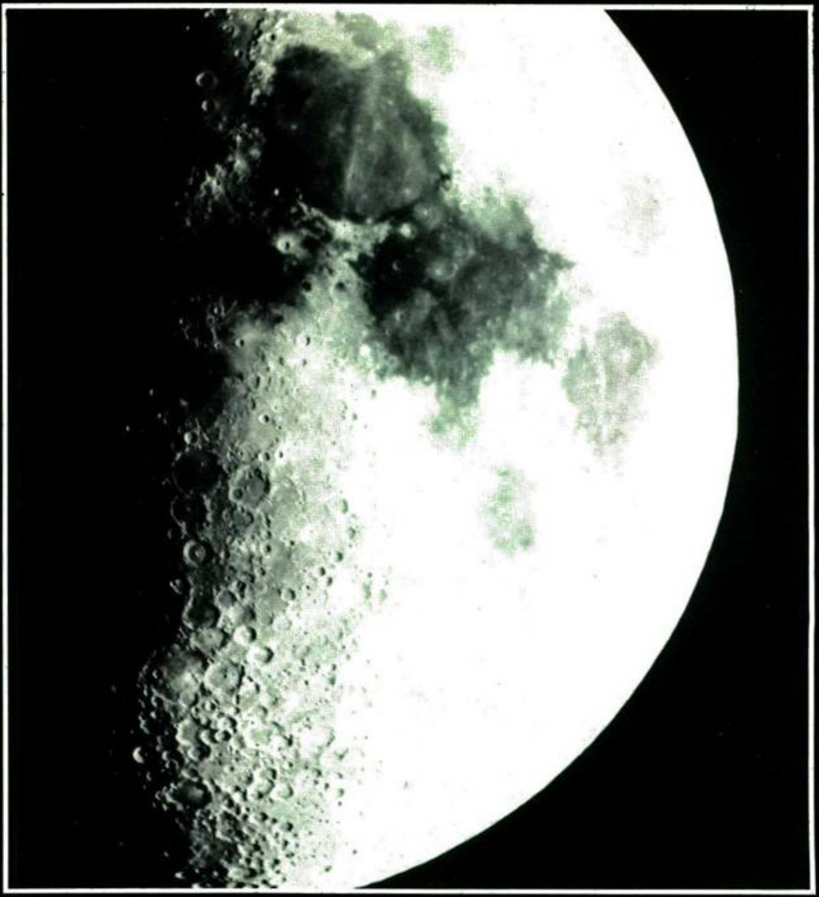
Effective Focal Length and Focal Ratio

Knowing the effective focal length and the effective focal ratio of an eyepiece-projection system is vital to getting good lunar and planetary photos. The effective focal length determines how large an image is formed on the film, and the effective focal ratio determines how quickly light builds up on the film and thus how long the exposure must be.

Unfortunately, these values are not always easy to determine. First you must calculate the magnification of your eyepiece-projection system. The magnification is the ratio of the image size produced by the system to the image size produced by the telescope's objective alone. Its value is given by the formula $m = y/f - 1$, where m is the magnification, y is the distance from the eyepiece to the film plane, and f is the focal length of the eyepiece.

The location of the film plane is often indicated by a small mark on the top or base of the camera body. If this spot is not marked on your camera, you'll have to estimate its location. The appropriate spot on the eyepiece is not marked, but it generally lies somewhat closer to the eye lens than to the field lens.

Once you have measured the eyepiece-to-film distance, plug it into the formula to obtain the system's magnification. The effective focal length is the magnification multiplied by the focal length of your telescope. The effective focal ratio is the magnification multiplied by the telescope's focal ratio.



In lunar photos the "correct" exposure time depends on the area you want to record. In David Hudgins' photo the limb is overexposed, while the terminator is underexposed. Only in a narrow band is the exposure optimal.

- Correct exposure: when the film is under- or overexposed, subtle details are lost.
- A high elevation for the object: the less air you photograph through, the better your pictures will be.
- Good seeing: you must have a steady atmosphere to produce a steady picture.
- A stable telescope: if it shakes, so will your pictures.
- Proper tracking: your telescope must accurately track the object to produce a sharp picture.
- Proper focus: an out-of-focus image results in an out-of-focus picture.
- Vibration-free exposure: if the camera vibrates during an exposure, the picture will be blurred.

To get superb photographs, you must insure that each of these factors is as close to perfect as you can make it. High-resolution astrophotography is difficult because *one* bad factor can ruin your pictures.

Good Optics

In eyepiece-projection photography the telescope and eyepiece act together as the camera's lens. If the quality of that lens system is poor, then the quality of the photographs will be poor too. High-quality refracting telescopes generally produce the best planetary photos, because these telescopes provide superior contrast. Long-focus Newtonian reflectors run a close second. Yet most budding astrophotographers already own a telescope and thus don't have a choice in that regard. What can they do to optimize their optical system's performance?

For a given telescope the quality of the eyepiece will determine how good the lunar or planetary image will be. Most Schmidt-Cassegrain telescopes come with Kellner eyepieces. Although these eyepieces are good for all-purpose work, they are not generally the best for planetary photography. Most lunar and planetary photographers feel a high-quality Plossl or orthoscopic eyepiece provides the best image for eyepiece-projection photography.

Eyepiece projection will let you take great photos of the Moon and planets.

Appropriate Film

You'll need a high-contrast, high-definition film to capture planetary detail. Why? Because most planetary details are subtle, low-contrast markings. For this reason the best black-and-white film for planetary photography is Kodak Technical Pan 2415. Kodak 2415 is significantly better than other black-and-white films in two additional areas: grain and resolution.

For high-resolution lunar photography a film with less contrast should be used — the Moon already has enough contrast. Tri-X and Plus-X, along with their newer counterparts TMax 100 and 400, are excellent choices.

If you want to shoot color photos, the best way to capture the planets or dramatic lunar craters is with medium-speed, good-definition slide films. Fujichrome 100 or 400, Kodachrome 200, or Ektachrome 200 or 400 are all good choices. Faster films are too grainy for these purposes. Slower films are difficult to use because optimal conditions must be maintained for longer periods of time. I would recommend against using slower films until you have mastered eyepiece projection with medium-speed films.

Correct Exposure

Exposure times in lunar and planetary photography depend on the film speed used, the effective focal ratio of your eyepiece-*projection* system, and the brightness of the object. Because the Moon and nearby planets are much brighter than deep-sky objects, exposure

Determining Exposure Times

The exposure time for an astrophoto depends on three factors: film speed, the effective focal ratio of your optical system, and the brightness of the object you are photographing.

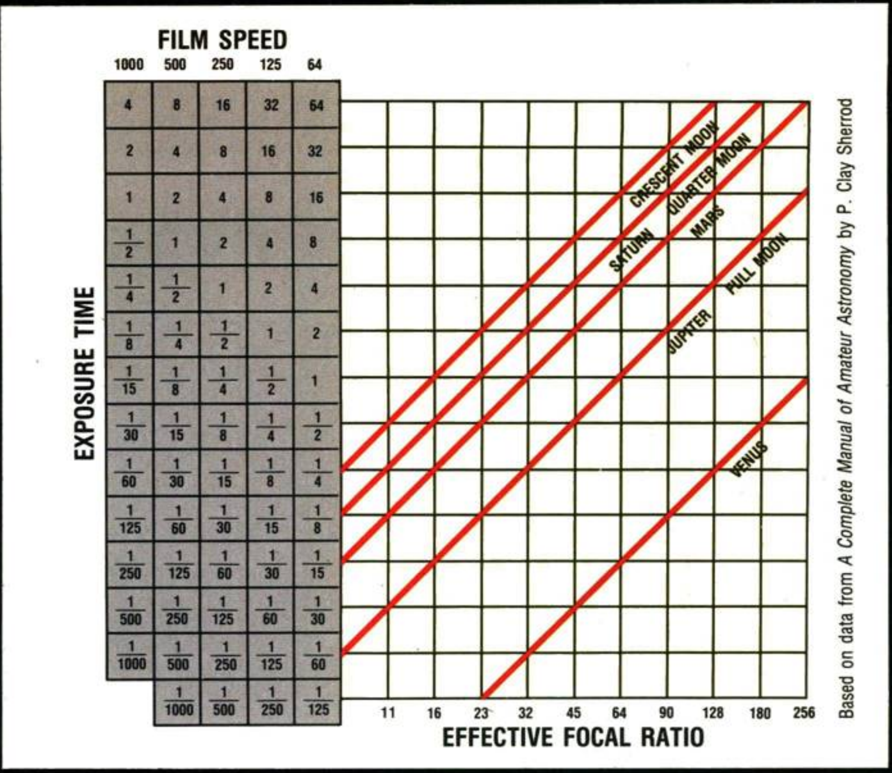
Fast films build up an image more quickly than slow films. This means, all other things being equal, that a faster film requires a shorter exposure time.

Large effective focal ratios result from the high magnifications obtained with eyepiece-projection systems. Because magnifying an image spreads it over a larger area, each part of the film receives less light. Thus, a larger focal ratio means a longer exposure time.

The surface brightness of the Moon and planets depends on how much sunlight each object receives and how much it reflects. The values used to develop the chart at right are approximations based on how bright each object appears from Earth under "average" conditions. Among the planets, Venus has the brightest surface, followed by Jupiter, Mars, and Saturn. The Moon is a special case because its average surface brightness varies depending on its phase and on the elevation of the Sun in the lunar sky.

To use the accompanying chart, first find the focal ratio of your eyepiece-projection system along the bottom of the graph. Follow the line above that spot upward until it intersects the diagonal line corresponding to the object you want to photograph. Finally, follow the horizontal line from the intersection to the left. The "correct" exposure time is listed under the speed of the film you will be using.

Because the brightness values used to determine these exposure times are only average values, you should bracket that exposure by taking photos one and two stops both faster and slower. This guarantees that at least one of your photos will be optimally exposed.



1000	500	250	125	64
4	8	16	32	64
2	4	8	16	32
1	2	4	8	16
$\frac{1}{2}$	1	2	4	8
$\frac{1}{4}$	$\frac{1}{2}$	1	2	4
$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2
$\frac{1}{15}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1
$\frac{1}{30}$	$\frac{1}{15}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$
$\frac{1}{60}$	$\frac{1}{30}$	$\frac{1}{15}$	$\frac{1}{8}$	$\frac{1}{4}$
$\frac{1}{125}$	$\frac{1}{60}$	$\frac{1}{30}$	$\frac{1}{15}$	$\frac{1}{8}$
$\frac{1}{250}$	$\frac{1}{125}$	$\frac{1}{60}$	$\frac{1}{30}$	$\frac{1}{15}$
$\frac{1}{500}$	$\frac{1}{250}$	$\frac{1}{125}$	$\frac{1}{60}$	$\frac{1}{30}$
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	$\frac{1}{1000}$	$\frac{1}{500}$	$\frac{1}{250}$	$\frac{1}{125}$

Based on data from *A Complete Manual of Amateur Astronomy* by P. Clay Sherrod

times for these objects are much shorter. Even Saturn, the dimmest of the standard targets, takes no more than several seconds to capture at the suggested film speeds and focal ratios.

A chart of recommended exposure times is given in "Determining Exposure Times." Because observing conditions usually differ from the "average" conditions used in computing the exposure times, you should bracket your exposures by one or two stops on both sides of the values given.

To get one good photograph of the Moon or a planet, you'll have to take many. You can't be stingy with film when you try high-resolution lunar and planetary photography. You may get only one or two good frames out of a thirty-six-exposure roll, but those will be worth the time and effort.

Target Elevation and Seeing

The chances of getting a successful photograph increase with the elevation of the object in the sky. The reason for this is quite simple: light from the object passes through less of Earth's atmosphere when the object is higher in the sky. Next time you're outside for an observing session, look at the stars near the horizon. Notice how they twinkle as their light passes through the moving layers of air? The stars overhead do not suffer the same fate because you see them through less atmosphere and the twinkling effect is minimized. The same situation affects photos of the Moon and planets. Although you won't see these objects twinkle when they are low in the sky, the quality of the photographic image will be degraded substantially.

Successful planetary photography requires atmospheric stability. Areas of atmospheric stability only occur when the barometric pressure remains steady, and this condition exists only when a high- or low-pressure system is situated over the observer. Because low pressure is associated with precipitation, good planetary observing requires a high-pressure system over the observer's location.

But a high-pressure system by itself is not enough to get the best possible photos. The dry air normally associated with high-pressure areas is great for deep-sky photography but not as good for planetary photography. Why? Because dry air is not as good a thermal "distributor" as humid air. We've all seen those "nice" clear nights when stars twinkle and dance about. The twinkle is caused by heat, absorbed by Earth's surface during the day and radiated into the atmosphere at night. The same radiation effect causes rippling water mirages in the desert.

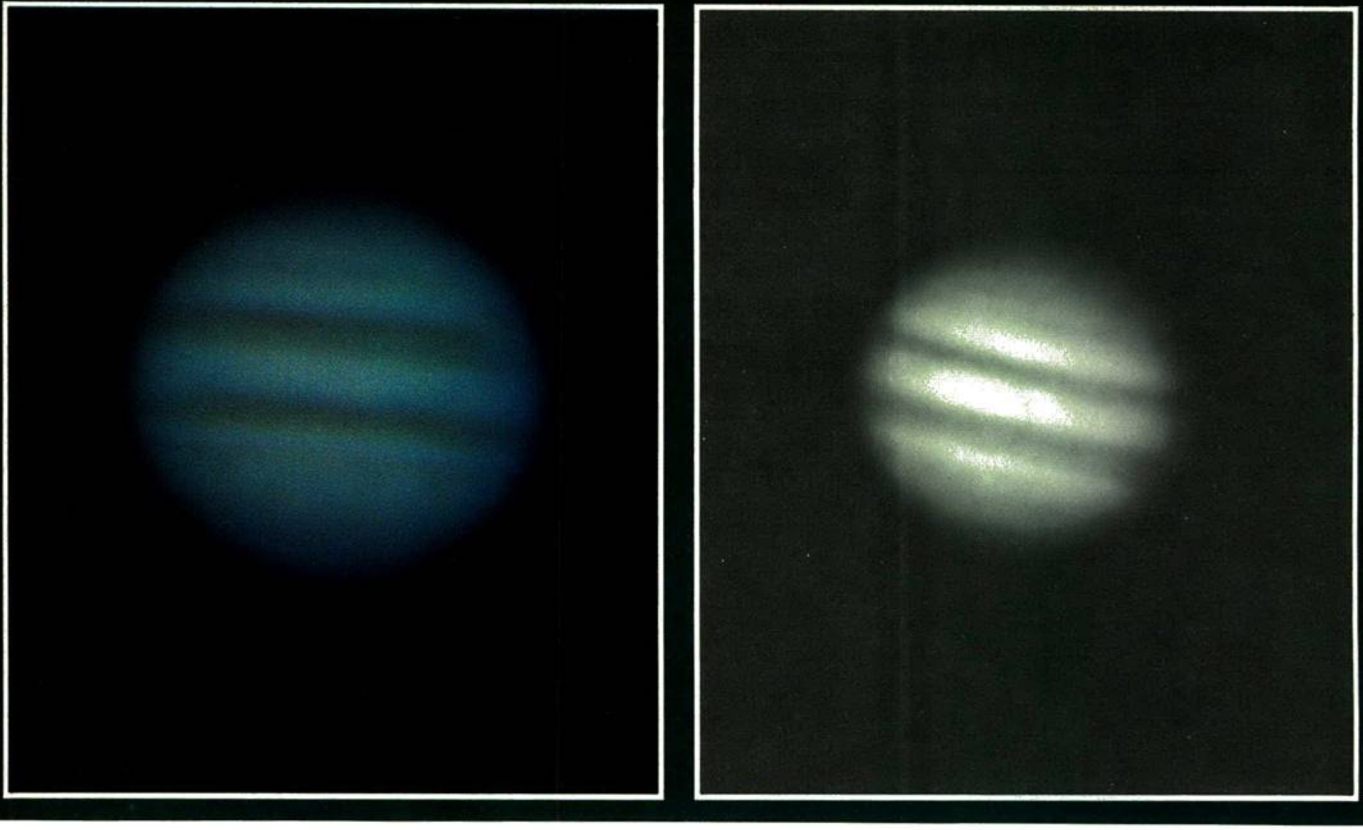
Heat movement back into the atmosphere usually begins shortly after sunset as the ground begins to cool and reaches a peak around midnight. By the early morning hours the cooling process has stabilized the temperature difference between the atmosphere and the ground. This is why the early morning hours — from about 1:30 a.m. on — are good times to attempt high-resolution astrophotography: these are usually the times of minimal heat movement. If you aren't an early morning person, the early evening hours offer a good alternative.

Humid air is more likely to distribute ground heat uniformly at night in such a manner as to cause a "temperature inversion." During such an inversion the atmosphere's temperature increases with height: cooler air is near the ground and warmer air is above it. This situation causes those hazy, hot, and humid nights of July and August, but temperature inversions can occur any time of year. These nights, particularly when a humid high-pressure system stalls, provide the best planetary seeing. There is no movement of air because of pressure instability and little movement because of heat radiating into the atmosphere.

Telescope Stability and Tracking

You can never take a successful long-exposure (greater than 1/4 second) photograph on an unsteady tripod. Think of

Below: The choice of color or black-and-white film is largely a matter of personal preference. Subtle color differences in Jupiter's cloud tops are the only significant detail that color film can reveal better than black and white. Black-and-white photo by Kim Zussman on Technical Pan 2415 with a 1-second exposure through an 11-inch SCT at f/148. Color photo by Rick Dilsizian on Kodachrome 64 with a 2-second exposure through a 14-inch SCT at f/105.



your telescope's mount and legs as one big tripod. Firm it up. Check the stability by gently nudging the camera and see how long the telescope takes to damp out the resulting vibration. If it takes more than two or three seconds, recheck all the supports and assemblies. Remember that the longer the telescope takes to stabilize, the lower your chances of getting that great astrophoto.

Even though exposure times in eyepiece-projection photography are relatively short, the large magnifications used amplify any tracking error. Make sure your clock drive is functioning properly by centering a star in the eyepiece and watching its movement. If the drive is accurate, the star will remain stationary. (Although the Moon and planets move at a slightly different rate than the stars, the difference is not important on short exposures.) Remember, any drift in right ascension or declination caused by poor tracking will blur the resulting photographic image.

You should also try to take a majority of your photos around the meridian. This improves image quality not only because there is less atmosphere to view through but also because this is the section of the sky where drift is smallest.

Proper Focus

You must be able to see the image clearly to get a sharp focus. This requires a clear focusing screen. Unfortunately, clear focusing screens are not usually supplied with most 35mm SLRs. Most 35mm cameras come with a ground glass screen that assures good focusing of well-lit objects. But these screens usually do not transmit much light. When you're taking lunar close-ups or photos of the planets, focusing through a ground glass screen is very difficult.

Some of the more sophisticated 35mm SLRs allow you to interchange focusing screens. If your camera has this capability, remove the ground glass screen and replace it with a clear focusing screen. Not only will this yield a clearer, brighter image, but it will also reduce the strain on your eyes.

Planetary observing is best in clear, humid weather during the early morning hours.

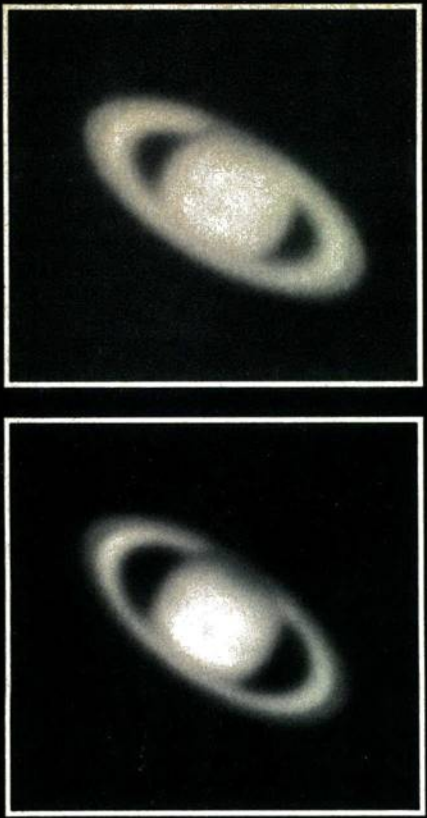
Even with the large magnifications used in eyepiece-projection photography, the image of a planet will appear very small in the view finder. This makes precise focusing a real challenge, even with a clear screen. Monitoring the planet's image for periods of good seeing is equally challenging. For these reasons, attaching a magnifier over the view finder to enlarge the projected image makes things easier.

Some 35mm camera models have this magnifying capability. Nikon, Canon, Olympus, and Minolta make magnifiers for many of their 35mm cameras. The best way to check whether or not your camera has this capability is to ask at your favorite photo or camera store. These magnifiers usually cost a good deal of money, but they do enlarge the image from five to ten times.

Even if you can't interchange focusing screens or get a focusing magnifier for your camera, you shouldn't give up. This little trick will still let you take good photos. Choose a bright star near your target object and carefully focus on that star. When the star appears as a pinpoint of light, it is in focus; then return to your original subject and that will be in focus too.

Vibration-Free Exposure

A significant problem in eyepiece-projection photography is mirror "slap," which occurs when the shutter button is pressed. The mirror flips up, out of the light path, and then the shutter opens. The



For black-and-white photography, Kodak Technical Pan 2415 film is the best choice. These two photos of Saturn were shot under identical conditions with a 14-inch SCT at f/105 and 4-second exposures. The top photo is on Tri-X and the bottom one on 2415. Photos by Rick Dilsizian.

Below: The high magnifications used in eyepiece projection reveal any flaws in your technique. This photo of the Moon's western limb is slightly blurred because the telescope's clock drive motor was not turned on and the telescope did not follow the Moon's movement across the sky. This 1/2-second exposure on Tri-X film was shot by Richard Talcott with a 3.5-inch Maksutov-Cassegrain telescope at f/66.

mirror later flips down after the shutter closes at the end of the exposure. In both instances the camera tends to vibrate slightly from the motion. At the large magnifications used in eyepiece-projection photography, however, even this tiny motion is enough to blur the photo.

A camera that minimizes this motion is the best solution, but there are two indirect techniques for alleviating the problem.

Some cameras have a mirror locking mechanism that allows you to lock the mirror out of the light path prior to taking the photo. Although this feature eliminates mirror slap, it does have a minor drawback. Because the mirror reflects light to the view finder, you can't see the target object when the mirror is locked up. This means you must focus the object ahead of time and hope the brief moment of excellent seeing lasts until the exposure is made.

The "black hat" method is a more effective way to minimize vibration. Place an opaque cover — a piece of cardboard, for example, or the traditional black hat — in front of the telescope's optics. Press the cable release and then wait two or three seconds until all the vibrations cease. At this point the shutter is open but the exposure has not yet begun because the front of the telescope is blocked. Take the cover away and begin the exposure. At the end of the exposure, cover the front of the telescope again and release the cable release to close the shutter. Because you can't monitor the object's image at the exact moment you begin the exposure, the period of best seeing may be gone before the picture is taken. Despite this, your results should be much better than if you used the camera with mirror slap.

Developing

Now that you've taken some great lunar and planetary photos, you need to get them processed. If you send your film to a commercial photo lab, make sure the first few pictures on the roll are of "normal" objects: your house, Uncle Bill, or the flower garden out back. This gives the lab processors a frame of reference so they will know where to cut the rest of the roll, which is where the lunar or planetary images are. And always include a note explaining what kind of pictures are on the roll. This alerts the lab staff to the unusual nature of your pictures so the staff doesn't mistakenly believe all the frames are blank.

Because I take a lot of Kodachrome 64 and 200 images and that is the one film I can't process myself, I send these rolls to the Kodak lab in New Jersey with an explanatory note. The lab always produces the slides without any hassle and the slides are all perfectly framed.

If you have access to a darkroom, I recommend developing your own negatives or slides. I have been doing it for years and find it both challenging and rewarding. For Technical Pan 2415 film I use 15 ounces (450 ml) of Kodak D-19 developer stock solution and 1/2 ounce (15 ml) of H&W Control Developer Concentrate mixed in. I develop the 2415 in this solution for approximately five minutes at 70° Fahrenheit. This produces an effective film speed of ISO 200 yet maintains the high contrast associated with the film.

Anyone who knows the important factors involved in high-resolution astronomical photography should be able to approach the subject with a firm, positive attitude. It may still take time to find the astrophotographer's "holy grail" — the perfect planetary photo — but now you can save the time, expense, and frustration of shaky, out-of-focus negatives along the way. That exceptional photo of Saturn is out there somewhere. Good luck and humid skies!

Rick Dilsizian is an assistant professor of mathematics and computer science at Westchester Community College in Valhalla, New York. His most recent article for ASTRONOMY, "Photographing Our Nearest Star," appeared in the May 1987 issue.

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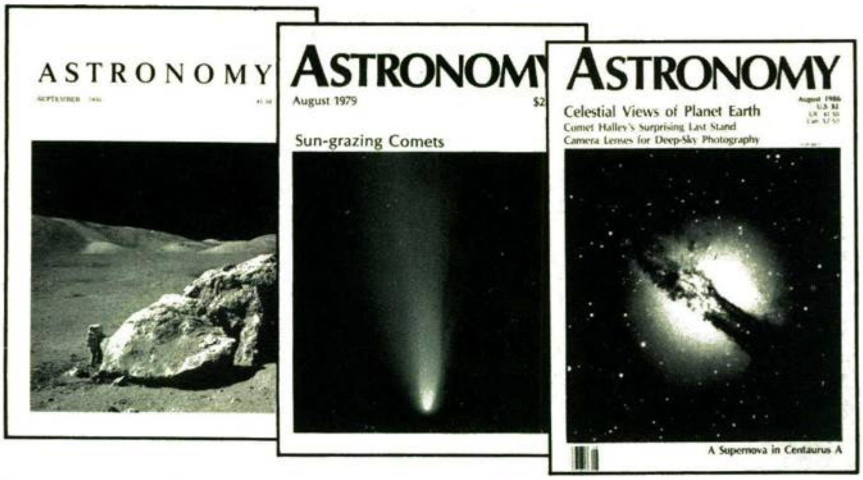
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Equipment Atlas

Tools for the Astrophotographer

High-resolution lunar and planetary photography is unlike any other type of astrophotography. A favorite subject of deep-sky photographers — galaxies — are typically several arcminutes across. The planets, however, are just a small fraction of this size. Enormous focal lengths are necessary to make the planets large enough to show up as more than specks of light on the film. Although the Moon appears much larger than the planets, individual features you'll want to record can be smaller than a planet.

Eyepiece projection increases the size of these images on the film. In essence, the telescope and eyepiece combination serves as the "lens" of the camera. The eyepiece magnifies the image formed at the prime focus of the telescope and projects this magnified image onto the film.

To attempt eyepiece-projection photography, you need to couple the camera body to the telescope so light exiting the telescope passes through an eyepiece before falling on the film. The telescope forms a small image of the object you are observing, which the eyepiece enlarges and projects toward the camera body. The camera body holds your film at the location where the magnified image is in focus.

In addition to the telescope, eyepiece, and camera body, you will need a tele-extender or camera adaptor (two different names for the same basic device) and a T-ring adaptor. The T-ring adaptor couples the camera to the tele-extender, and the tele-extender establishes a solid mechanical link between the eyepiece and the camera body. This equipment is readily available from telescope manufacturers and independent dealers, relatively inexpensive, and simple to set up and use.

Attaching the Tele-Extender

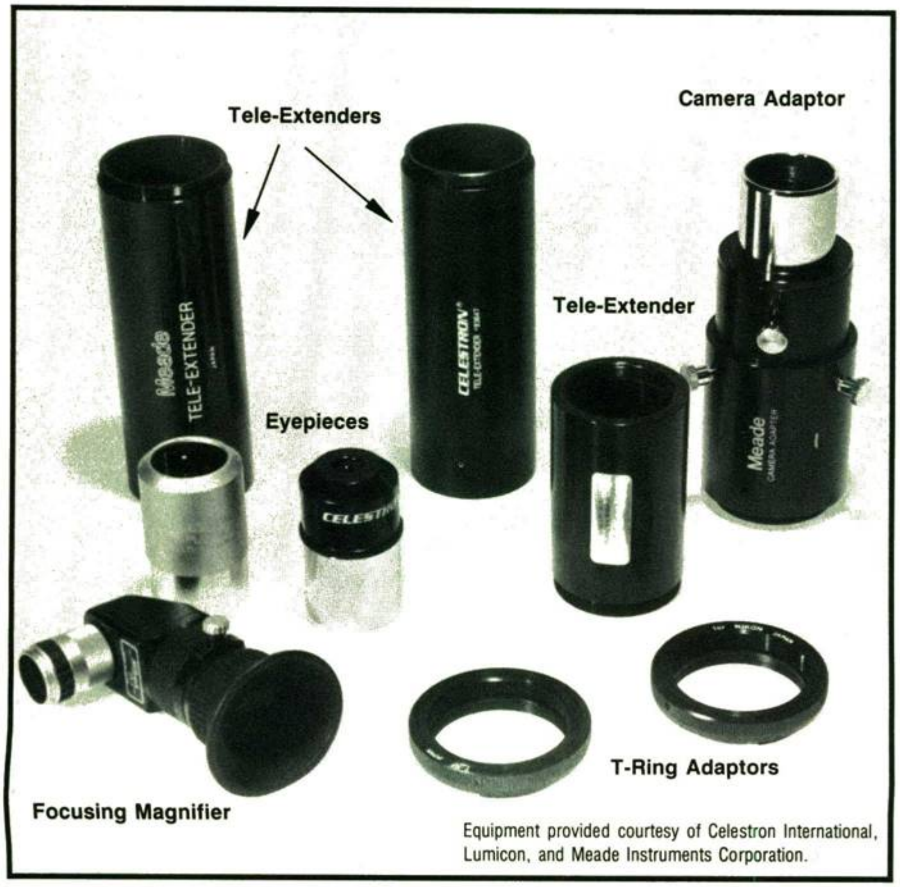
The type of telescope you own determines how all the elements work together. In particular, the type of tele-extender you use and how it attaches to the telescope and eyepiece differs from a Schmidt-Cassegrain telescope (SCT) to a Newtonian.

To install the tele-extender on a SCT, you must first insert an eyepiece into the "visual back" of the telescope. The tele-extender is threaded on both ends: on the outside of the tube at one end and on the inside of the tube at the other end. Simply screw the end of the tele-extender with the threads on the inside onto the visual back of the telescope over the eyepiece.

The procedure for a Newtonian telescope is slightly more complicated. In this case a camera adaptor performs the same function as the tele-extender does with a SCT. The adaptor comes with an attachment that couples to the eyepiece opening of your telescope. Merely screw this attachment into the narrower end of the adaptor.

Now comes the tricky part. You must place the eyepiece *inside* the adaptor. Carefully slide the eyepiece down the tube until it comes to rest against the top of the attachment you just installed.

The next step is crucial but easy to overlook: Tighten the eyepiece locking screw

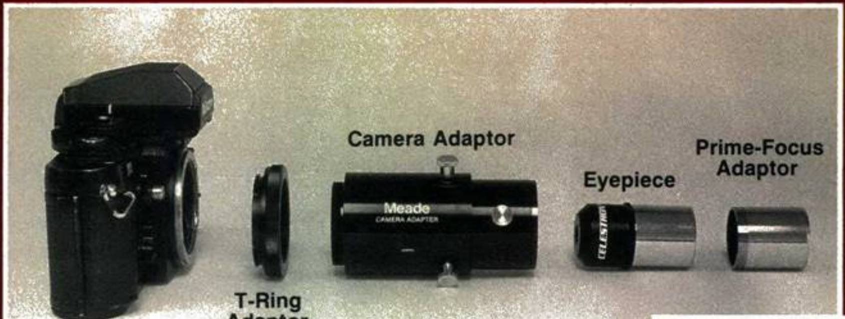


Equipment provided courtesy of Celestron International, Lumicon, and Meade Instruments Corporation.

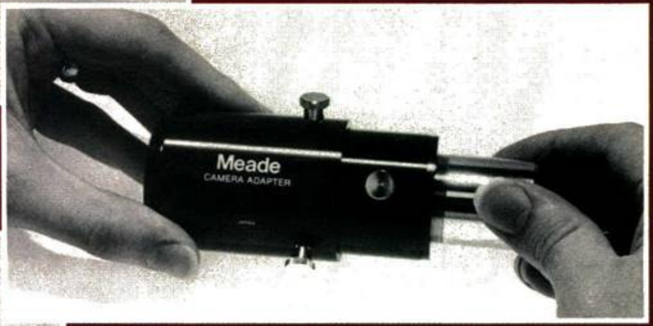
A representative sample of equipment for eyepiece-projection photography. Tele-extenders are for use with Schmidt-Cassegrain telescopes; camera adaptors are for use with all types of telescopes. All photos by Art Schmidt.

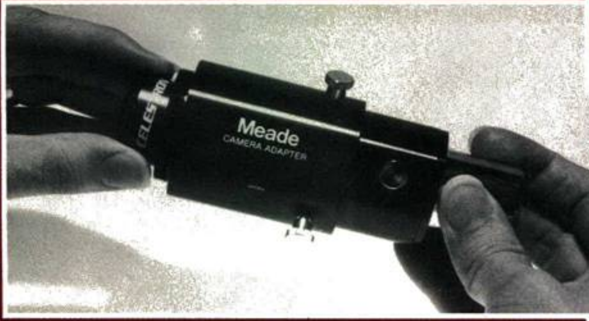
Assembling an Eyepiece-Projection System

An exploded view of the eyepiece-projection setup for a Newtonian reflector shows the relative location of each piece of equipment needed. The eyepiece fits inside the camera adaptor.

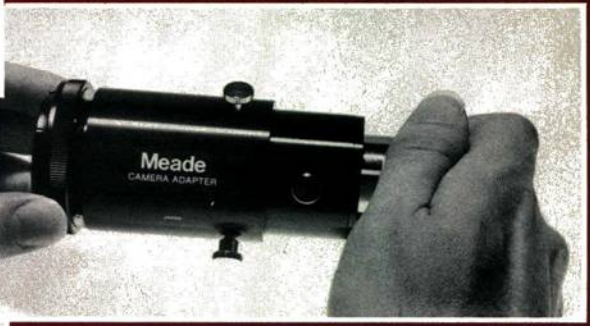

Camera Adaptor
Prime-Focus Adaptor
Eyepiece
Meade CAMERA ADAPTER
CELESTRON
T-Ring Adaptor
Camera

To assemble the eyepiece-projection system, first screw the prime-focus adaptor into the base of the camera adaptor.

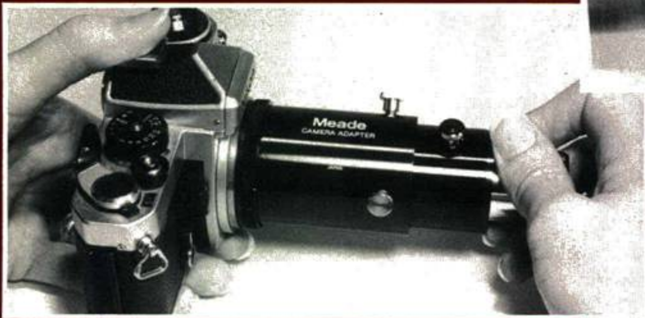

Meade CAMERA ADAPTER


Meade CAMERA ADAPTER
CELESTRON

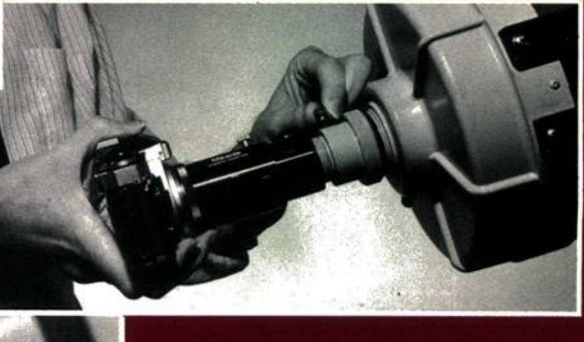
Insert an eyepiece into the top of the camera adaptor and slide it down the length of the tube.


Meade CAMERA ADAPTER

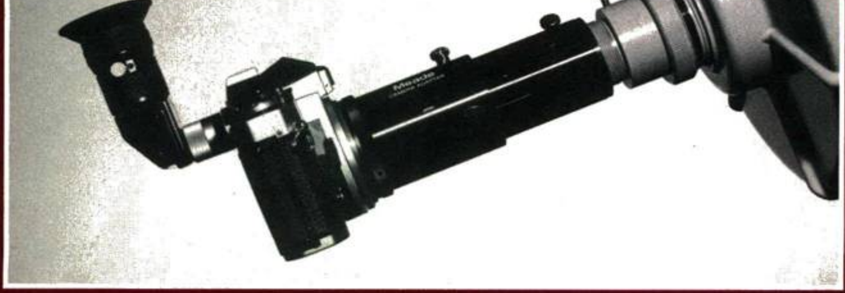
Make sure the eyepiece is locked securely into place and then screw the T-ring adaptor into the top of the camera adaptor.


Meade CAMERA ADAPTER

Join the assembly to the camera body. The T-ring adaptor couples to the camera body the same way a normal camera lens does.



Finally, attach the assembly to the telescope. Insert the prime-focus adaptor into the eyepiece holder and tighten the thumbscrew.

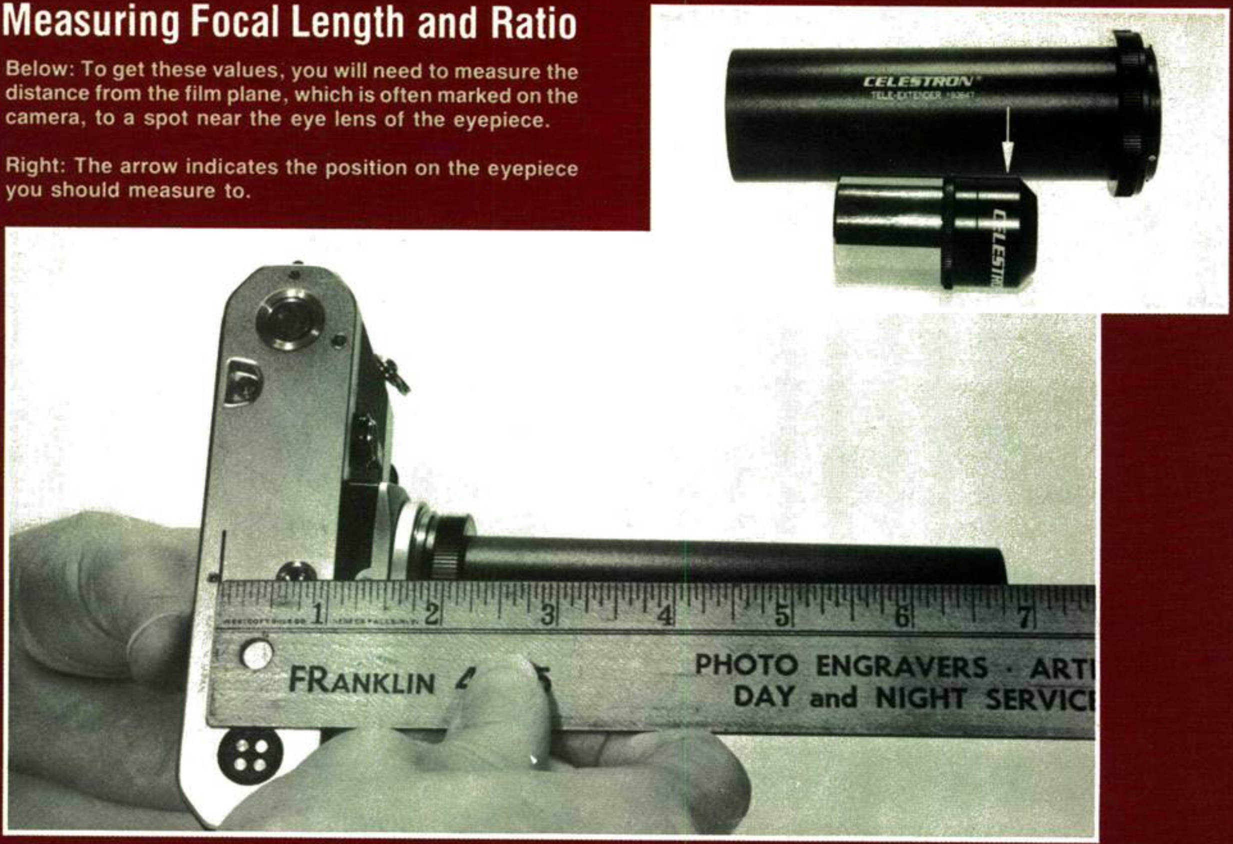

Meade CAMERA ADAPTER

The entire eyepiece-projection system forms a single unit that significantly enlarges the lunar or planetary image formed by the telescope. Light passes from the telescope to the eyepiece (located inside the adaptor) and is projected down the tube of the camera adaptor to the camera itself. A focusing magnifier attached to the camera aids in focusing the dim image.

Measuring Focal Length and Ratio

Below: To get these values, you will need to measure the distance from the film plane, which is often marked on the camera, to a spot near the eye lens of the eyepiece.

Right: The arrow indicates the position on the eyepiece you should measure to.



until you are *sure* the eyepiece is firmly in place. If you forget to do this, the eyepiece will slide out of the adaptor and could then damage the inside of your camera.

With the eyepiece secure, insert the camera adaptor into the telescope the same way you would an eyepiece. Because the adaptor connects to the telescope the same way an eyepiece does, the Newtonian adaptor will also work on a SCT — but the SCT tele-extender will not work on a Newtonian.

If you own a refractor or other telescope that uses standard 1-1/4-inch eyepieces, the Newtonian camera adaptor should work on your scope. For any other style of telescope contact the manufacturer; most manufacturers supply eyepiece-projection equipment for their own lines.

Suppliers of Eyepiece-Projection Equipment

Celestron International
P.O. Box 3578, Torrance, CA 90505
Lumicon
2111 Research Drive #5
Livermore, CA 94550
Meade Instruments Corporation
1675 Toronto Way
Costa Mesa, CA 92626

Three manufacturers offer tele-extenders or camera adaptors for eyepiece-projection photography. A tele-extender is a projection tube for a SCT; a camera adaptor can be used with Newtonians, refractors, and SCTs. Meade offers a standard tele-extender for $50, Celestron's model retails for $40, and Lumicon's costs $32. Dealers often discount these prices.

The inside of each tele-extender is designed to reduce reflections from scattered light. The Celestron model, which is internally threaded, anodized black, and matte black inside, has the lowest level of scattered light. The Meade and Lumicon tubes are threaded and anodized black.

Meade and Lumicon also make camera adaptors. These are versatile, two-part systems that can also be used for prime-focus photography. The Meade model includes a sliding mechanism that allows you to change the projection magnification without changing eyepieces. Meade's camera adaptor retails for $80 with dealer discounts common; the Lumicon model costs $32.

The best tele-extenders and camera adaptors have a dark, light-trapping interior. This is to prevent scattered light from making its way down to the camera and ultimately onto the film, fogging your pictures. (Scattered light is rarely a problem with planetary photos but can be a real nuisance with lunar photos.)

Getting the Camera Ready

The final two steps are easy. What you need to do next is attach your camera to the tele-extender. First take the T-ring adaptor and screw it onto the end of the tele-extender with the threads on the outside.

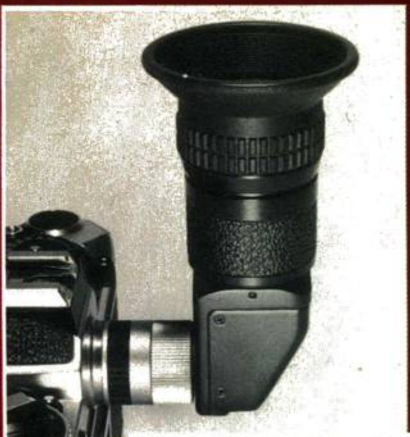
The final step is attaching the camera to the rest of the assembly. The T-ring adaptor presents the same face to the camera as a normal lens does. Simply take the lens off your camera and attach the camera body to the T-ring adaptor.

Different camera brands require different T-ring adaptors. When placing your order for eyepiece-projection equipment, specify the type of camera you own. (Most manufacturers, dealers, and camera stores carry T-ring adaptors for a wide variety of major brands.)

Achieving Different Magnifications

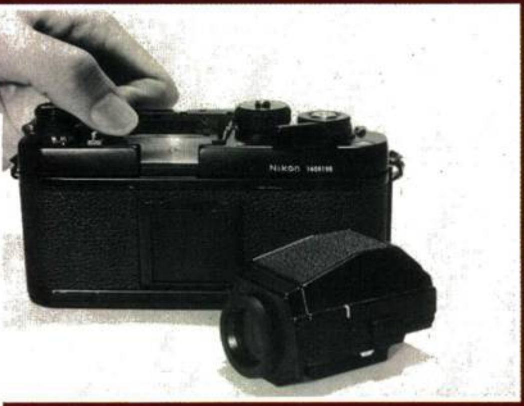
Most photographers use or would at least like to use more than one camera lens. Likewise, lunar and planetary photographers like to use more than one magnification. Just as a range of different

Important Camera Accessories



Left: A focusing magnifier enlarges the image in the view finder so you can see a planet's image better. This helps you to focus the image more sharply.

Below, left: A cable release lets you depress the shutter on the camera without having to touch — and probably jiggle — the camera body.



Below: Replacing a ground glass focusing screen on your camera with a clear focusing screen makes seeing and focusing dim planetary images easier.

lenses allows a photographer to choose the best lens for a specific purpose, using different projection magnifications allows an astrophotographer to get the best image he can of the Moon or a planet.

For example, a close-up of cloud patterns on Jupiter or of dusky surface features on Mars requires a relatively long effective focal length, while a shot showing the southern highlands on the Moon can be done at a comparatively short focal length.

There are two ways to change the effective focal length: by switching eyepieces or by varying the projection distance. You know from visual observing that a shorter focal-length eyepiece gives you a bigger image. Well, the same thing happens in eyepiece-projection photography. The easiest way to increase your optical system's magnification is to switch to a shorter focal-length eyepiece.

The second way of varying the effective focal length is to modify the distance over which the image is projected. The variable-projection camera adaptor from Meade Instruments lets you alter the position of the eyepiece relative to the camera body and thereby get different projection distances. Most other camera adaptors and tele-extenders provide for little or no eyepiece movement.

Changing eyepieces and varying the projection distance have equal effects on the system's magnification. For example, choosing an eyepiece that has half the focal length of another lens produces the exact same result as increasing the projection distance by a factor of two.

Increasing the projection distance moves the camera farther from the telescope and therefore increases the torque acting on the telescope. This tends to make the telescope less stable and also amplifies the effects of any vibrations in your system. For this reason changing eyepieces is preferable for getting really large magnifications. On the other hand, longer focal-length eyepieces used with long projection distances generally give images that are sharper at the corners of the field. When you find an eyepiece and projection distance combination that works well, stick with it for most of your lunar and planetary photos.

Camera Accessories

The large magnifications used in eyepiece-projection photography require more from your camera body than normal photography does. You should have a 35mm single lens reflex camera, and that camera must have a detachable lens.

Because of the high focal ratios attained in eyepiece projection, the image is usually dim and difficult to see. Two accessories can help you alleviate this problem. If your camera has interchangeable focusing screens, install a clear focusing screen instead of the standard ground glass screen that came with the camera. This will help you see the object more clearly. To see details on the object more clearly, a focusing magnifier will enlarge the image you see in the view finder, which makes it easier for you to monitor details for moments of superb seeing.

The long focal length you will be using also magnifies any vibrations that occur during an exposure. A cable release, preferably an air-pressure activated one, helps reduce the vibrations caused by pressing the shutter button. Finally, the vibrations produced when the mirror inside the camera body flips out of the light path can be eliminated with a camera that allows you to lock up the mirror (although the "black hat" method works just as well, if not better).

Although these may seem like minor points, they can spell the difference between good photos and outstanding photos. If these accessories and features are available for your camera, use them.

Eyepiece-projection photography takes a lot of work, and the rewards will not come quickly. But with the right technique, the proper equipment, and a bit of patience, you'll produce photos of the Moon and planets you'll be proud of. Eyepiece projection is not easy, but the reward is worth it.

— *Richard Talcott*

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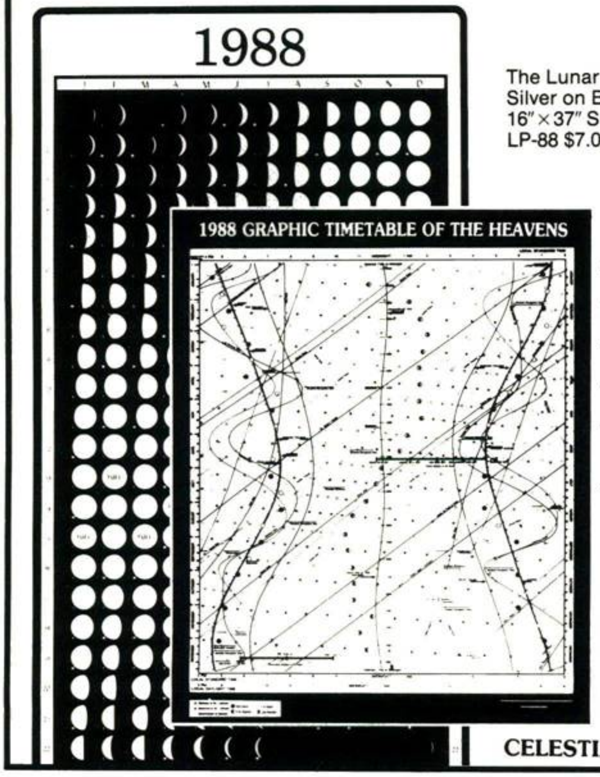

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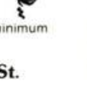

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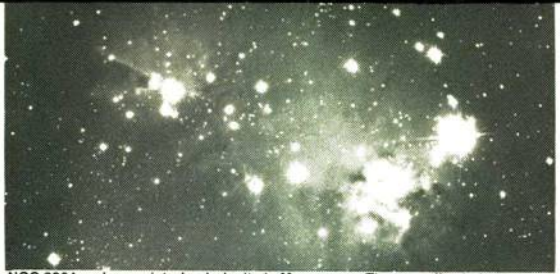

Open Cluster NGC 2264 and associated nebulosity in Monoceros. The "cone" nebula (dark protrusion) is to the left and bright star S Monocerotis is to the right; north is to right. This nebulosity has very low surface brightness, and reliable visual sightings of the cone nebula are not yet reported; try a LUMICON H-Beta filter or a LUMICON Oxygen-III Filter. NGC 2264 is best photographed with a LUMICON DEEP-SKY Filter. Photo by Bill Sorrells, 16" f/5, hyper 2415 film, 40 minutes using a LUMICON 2" EASY-GUIDER™

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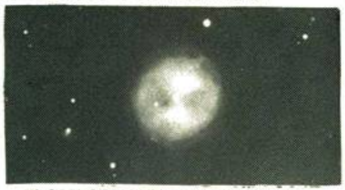

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The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 90-95%.

	Standard	**Premium***
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces		$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces		$79.50
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS		$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$99.50	$119.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		$299.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$79.50	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$159.50	$199.50
Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%)		$159.50
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. . . . . **1¼" $89.50** **48mm $189.50**		
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines . . . . **1¼" $99.50, 48mm $199.50**		
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		$6.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		$20.00

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

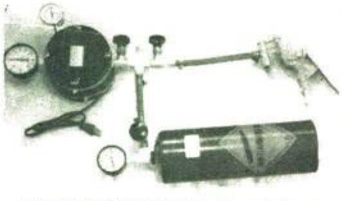
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of nonflammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller . . **$595.00**

Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump, Model R-10 **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent #4,448,500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$79.50**
Illuminated reticle eyepiece system	**$89.50**

Guider for Hasselblad **$350,** Mamiya 645 **$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**
CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$185,** Mamiya 645 **$159**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**
GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) . . . . . . **add $99.95**
Adapter for Hasselblad **$195,** Mamiya 645 **$96**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$89.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures . . **$9.95**

3. **LUMICON Quartz Drive Corrector** **$219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) .. **$70**
NEW Deluxe Digital Qtz. Drive Correc. **$298**

NEW **SRV3200**

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	$10.95
SRV3200, fastest of all, color neg	24	$13.95
Konica SR1600, very fast, fine gr.	24	$12.95
Konica SR400, fine grain color neg	12	$10.95
3M 1000, fastest slide film	12	$12.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

NEW LUMICON® PRODUCTS

LUMICON, 2111 Research Dr., #5
Livermore, CA 94550 (415) 447-9570

NEW! NON-ROTATING HELICAL FOCUSER

LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a 6'' telescope.

LUMICON has just designed a deluxe smooth helical focuser with non-rotating 2'' i.d. eyepiece holder. It has a vertical travel of 1¼'' and a very low profile only 1½'' high. It is CNC machined, black anodized, and a perfect match to LUMICON EASY-GUIDERS.

Select your desired base-plate shape! Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 20'' OD, SUPER-FINDER base plate.

LUMICON Deluxe Helical Focuser ...	**$79.50**
3 handles (see photo)	**$12.95**
Helical focuser with 3 handles	**$92.40**
2''/1¼'' adapter w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$169.50**

EYEPIECE PROJECTION

These adapters allow high magnification photography of the Moon and Planets using eyepiece projection. They may be used without any eyepiece for prime-focus photography. All adapters use standard camera T-rings.

Tele-Extender for Meade or Celestron SCT.	**$32**
1¼'' Basic Camera adapter, 2 part system	**$32**
0.96'' Basic Camera adapter, 2 part system	**$32**
1¼'' prime Focus adapter, fits 1¼'' focuser	**$22**
0.96'' prime Focus adapter, fits 0.96'' focuser	**$22**
Camera T-ring, specify 35mm camera type	**$12**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

1¼'' 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼'' straight-thru 80mm SUPER-FINDER ...	**$169**
1¼'' right-angle version, w/star diagonal	**$195**
2'' right-angle version, non-rotating focuser ..	**$199**
1¼'' Deluxe right-angle Super-Finder*	**$279**
2'' Deluxe right-angle Super-Finder*	**$309**
25mm Cross-hair 1¼'' eyepiece (12X)	**$29**
*1¼'' Star Diag. **$32**, 2'' Star Diag., silver,	**$145**
1¼'' Amici Prism diag. for correct left-right views	**$59.50**

2'' ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2'' operation. They allow use of 2'' accessories, such as the LUMICON 2'' EASY-GUIDER for photography. They also allow use of 2'' eyepieces and/or 2'' star diagonal for viewing.

2'' adapter for C-8, Meade 2080, etc....	**$26.00**
2'' adapter for Criterion 4000, 8000 ...	**$26.00**
2'' adapter for C-80, C-90, C-100	**$39.50**
2'' adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2'' Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	**$30.00**
2'' adapter for Takahashi E-130, 160 ..	**$59.50**

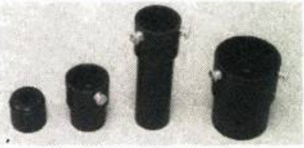
COMA CORRECTOR MULTIPLIER - 2'' BARLOW

These custom-designed LUMICON lenses correct aberrations in f/4 to f/5 Newtonians, and thread directly into LUMICON 2'' Easy-Guiders. The LUMICON Coma Corrector/Field Flattener improves photographic star images for fast Newtonian telescopes by correcting coma and flattening the field. Off-axis star images are much smaller, making off-axis guiding easier, and reducing the off-axis star image size in photos. The LUMICON Multiplier/Field Flattener multiplies the image scale by 1.8X (f/4.5 becomes f/8) with the included extension tube (1.5X w/o extension). The multiplier may also be used visually as a highly corrected 2'' Barlow lens. Lens designs are optimized for f/4.5 and all surfaces are multi-coated.

48mm Coma Corrector/Field Flattener	**$285.00**
1.5X/1.8X Multiplier/Field Flattener .	**$195.00**
LUMICON 2'' Easy-Guider (St. camera)	**$169.50**

VIEWING ADAPTERS

2''/1¼'' Adapter, threaded 48mm filters ..	**$20**
2''/T - Thread adapter, threaded 48mm ..	**$25**
T - Thread/1¼'' adapter. Converts telephoto lenses for viewing as finderscopes	**$25**



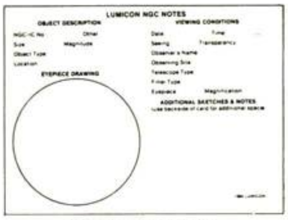
EXTENSION TUBES

1.0'' long Thread-in extension tube	**$12.00**
1-2½'' long, threaded for 1¼'' filters	**$16.00**
4½'' long extension tube, 1¼'' i.d.	**$25.00**
2'' i.d. Extension tube, 3'' long, threaded for 48mm filters, adds 1.6-3.0''	**$26.00**

48mm COLORED GLASS FILTERS

These 48mm Filters thread into LUMICON EASY-GUIDERS and most 2'' eyepieces. Use adapter for 1¼'' eyepieces. AR Coated.

Filter:	Bandpass	Trans	Price
Ultraviolet	320-420nm	85%	**$35**
Minus Violet	420nm-IR	96%	**$29**
Blue Tricolor	340-470nm	80%	**$35**
Hi Perf. Blue	300-540nm	95%	**$35**
Yellow	480nm-IR	98%	**$18**
Green	490-590nm	60%	**$18**
Orange	560nm-IR	98%	**$18**
Red	600nm-IR	98%	**$18**
H-Alpha Pass	640nm-IR	95%	**$35**
Cyan	340-580nm	95%	**$59**



LUMICON NGC NOTES

OBJECT DESCRIPTION

VIEWING CONDITIONS

EYEPIECE DRAWING

NGC NOTES

These handy **NGC NOTES** are stiff 4''X5½'' cards. the **NGC NOTES** fit in your hand and are ideal for making notes and sketches while observing at the eyepiece. Making sketches **greatly improves** your observing skills and also gives you a permanent record. Get 200 **NGC NOTES** for Messier objects; NGC object observers should get 400-800 **NGC NOTES.**

NGC NOTES, Pack of 200 .... **$9.95**
Pack of 400 **$17.95** Pack of 800 **$32.95**

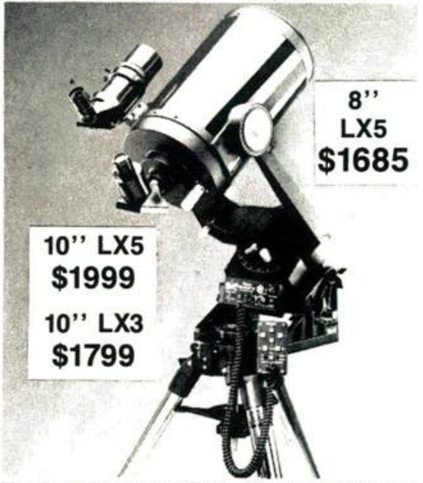
Meade® TELESCOPES AT LUMICON

New Meade MTS telescopes in stock!
6'' f/4 **$595**, 8'' f/4 **$895**, 8'' SCT **$895**, 10'' SCT **$1495**
Call for details on available options for MTS telescopes

NEW! 2080/LX5 .... $1685
MEADE 2120/LX5 .... $1999

The most advanced Schmidt-Cassegrain telescope available! *Standard equipment* includes dual-axis hand-held electronic command center, 2'' mirror star diagonal, 9X60mm polar viewfinder, multi-coated/enhanced optics, 26mm Super Plossl, tripod and wedge.

#39 Electric declination for 2080 or 2120/LX5	**$109**
Dew shield-essential 8'' (#712) **$65**; 10'' (#710)	**$98**
Accessory shelf for field tripod ($40 list)	**$28**
LUMICON EASY-GUIDER/Rich-Field viewer: for 2080 (f/6 operation) **$225**; for 2120 (f/4-f/10 operation)	**$395**
Computer control system, 8000 object memory	**$1495**



Meade 8'' Model 2080/LX5: Shown with *standard-equipment* 9X60mm finder, dual-axis controller, 2'' Diagonal Mirror, Equatorial Wedge, Field Tripod.

10'' Meade 2120/GEM ONLY $1799

10''
$1799
$998
8''
w/MCSO

Meade 2120/GEM (left) and 8'' 2080/GEM Schmidt-Cassegrain optics on German Equatorial Mount.

2080/GEM, 8'' f/10 w/MCSO, equatorial mount	**$998**
2120/LX3 10'' f/10 w/MCSO, wedge, tripod .	**$1799**
2120/GEM, 10'' f/10 w/MCSO, equatorial mount	**$1799**
Dew shield & accessory tray, 8'' **$72;** 10''	**$144**
#784 Motor & quartz drive corrector ($310 list)	**$219**
Computer Control system, 8000 object memory	**$1495**
Solar Filter for 2080 ... **$149;** for 2120 ...	**$185**

4'' MEADE 2045 w/table tripod $595

4'' f/10 Meade 2045/LX3 w/quartz drive	**$795**
#36 dual-axis cont. (LX3) **$99,** #38A dec. motor	**$99**
Wedge & field tripod for Meade 2045 ($380 list)	**$298**
Dew shield ($80 list) .. **$55;** Solar Filter ..	**$95**

FILTERS STOP POLLUTION

LUMICON UHC Filter™ for nebulae. Standard 1¼''	**$79**
Prem 1¼'' **$99;** Std 48mm **$159.50;** Prem 48mm	**$199.50**
LUMICON Deep-Sky Filter™, 1¼'' Premium ...	**$79**
48mm Prem Deep-Sky **$119.50, $99.95** w/Easy-Guider	
Adapter for viewing w/1¼'' eyepiece	**$20**

PHOTOGRAPHY ACCESSORIES

LUMICON Newtonian Easy-Guider, 1¼'' or 2''	**$169**
LUMICON Cassegrain EASY-GUIDER for Meade 2045, 2080/LX5 and 2080/GEM (state camera)	**$225**
Illuminated reticle eyepiece & battery pack	**$89.50**
Dual-axis Drive corrector	**$219**

These Meade Telescopes are complete and ready for viewing.

They include telescope with all coated optics for high transmission, mount, tripod or pier with legs, motor drive (except models 6600, 8800, GEM series). Finderscope, at least one eyepiece, and complete instructions. Call or write LUMICON for full technical information. MCSO means multi-coated silvered optics.

MEADE NEWTONIAN TELESCOPES

**16'' f/4.5
MEADE
DS-16A
only
$1975**

Note: Astrophotographers should order optional sealmaster ball bearings for the DS-16A (add $229).

Model 6600, 6'' f/5 w/1¼'' focuser, 6X30 finder	**$685**
Model 628c, 6'' f/8 w/motor, 2'' focuser, 8X50 finder	**$798**
Model 645c, 6'' f/5 w/motor, 2'' focuser, 8X50 finder	**$829**
Model 8800, 8'' f/4.5 w/1¼'' focuser, 6X30 finder	**$895**
Model 826c, 8'' f/6 w/motor, 2'' focuser, 8X50 finder	**$975**
Model DS-10A, 10'' f/4.5 w/motor, 2'' focuser ..	**$995**
Model DS-16A, 16'' f/4.5 w/motor, 2'' focuser .	**$1975**
Sealmaster ball bearings for DS-16A, recommended!	**add $229**
Finderscope for DS-10A, DS-16A, 8X50mm incl. mount	**$109**

All foreign orders add 6% ($8 minimum). California residents add 6% tax. Prices subject to change w/o notice. Set Meade and LUMICON Catalogues $4. **LUMICON, 2111 Research Dr., #5, Livermore, CA 94550.** Call **(415) 447-9570** for information & orders. Store Hours: M-F 9am-5pm; Sat 11am-3pm. All telescopes shipped F.O.B. Livermore.

AstroNews

100-Inch Mount Wilson Telescope to Reopen

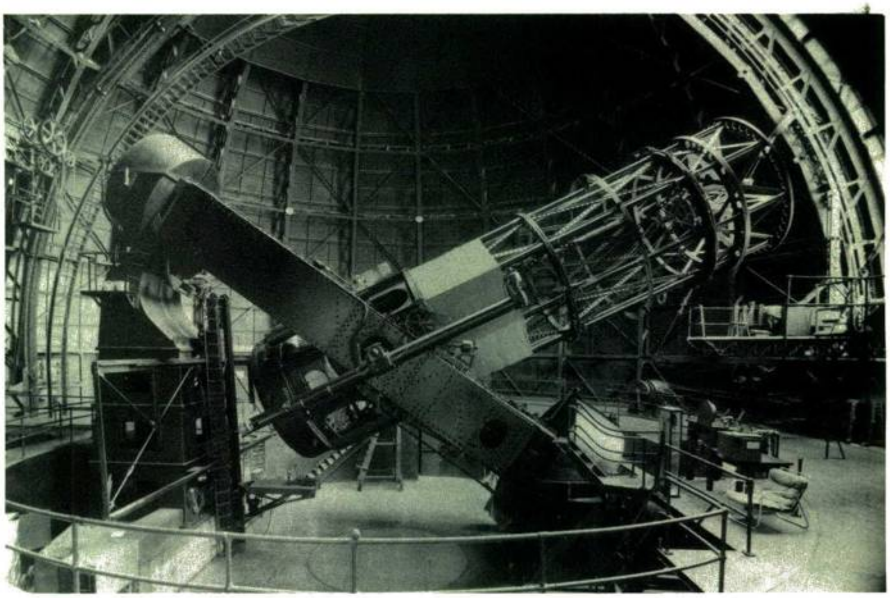
The historic 100-inch Mount Wilson telescope will reopen under the auspices of the Mount Wilson Institute. The announcement, made jointly on October 26, 1987, by the Carnegie Institution of Washington, the present owner of the observatory, and the Mount Wilson Institute, a nonprofit corporation, means that one of the finest astronomical sites in the world will remain active for many more years.

The historic instrument has been mothballed since June 1985, when the Carnegie Institution decided to concentrate its resources on the development of facilities at its Las Campanas Observatory in Chile (see "Reach for the Stars: The Story of Mount Wilson Observatory" by Joseph M. Horodyski, December 1986). The Mount Wilson Observatory also includes a 60-inch telescope and two large solar telescopes.

The Mount Wilson Observatory has long been a historical and cultural landmark in southern California. Arthur H. Vaughn, speaking for the institute, said that as well as continuing astronomical research, the institute's plans include developing the observatory's 5,800-foot-high mountain site for public education and recreation.

The Mount Wilson Institute is governed by a board of trustees from the business, legal, educational, and scientific communities. The board also includes representatives of the Los Angeles County Department of Parks and Recreation, the Los Angeles County Museum of Natural History, and the Carnegie Institution of Washington. An advisory council of internationally recognized scientists reviews the institute's work and objectives.

Mount Wilson's importance stems not only from the observatory's major scientific facilities but also from the atmospheric characteristics of the site, which make it outstanding for spectroscopic observations of stars. Mount Wilson offers three hundred clear nights per year and exceptionally good atmospheric "seeing." The spectroscopic programs planned are less affected by light pollution from the nearby Los Angeles basin than other types of astronomical work.



The 100-inch Hooker reflector on Mount Wilson will go back into service under the auspices of the Mount Wilson Institute. Photo courtesy of Mount Wilson and Las Campanas Observatories.

The Mount Wilson Observatory is and will continue to be privately operated, so it can be used to pursue long-term research projects that are usually not possible at national facilities. This is important because many important stellar phenomena, such as stellar "sunspot" cycles, occur only over long periods of time, and detecting and studying them requires observing programs that extend over equally long periods. By using the Mount Wilson telescopes primarily for such projects, the observatory will continue to make major scientific contributions well into the next century.

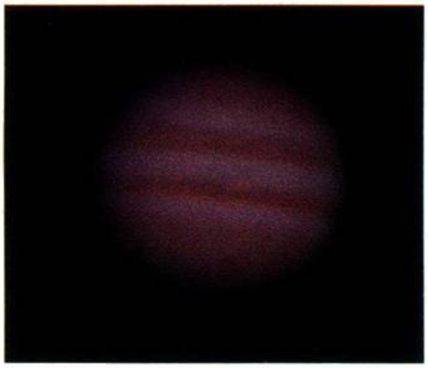
Another major goal of the Mount Wilson Institute is increased public educational and recreational use of the mountaintop. Direct involvement of Los Angeles County's Department of Parks and Recreation and Museum of Natural History should greatly contribute to such programs.

In a September 17 decision the Executive Committee of the Carnegie Institution's Board of Trustees expressed a willingness to turn the operation of the Carnegie Institution's facilities on Mount Wilson over to the institute, and, if appropriate for such operation, to transfer title to the observatory's buildings, equipment, and property. These steps are subject to the institute's procurement of financial resources, approval by the U.S. Forest Service (the lessor of the land), and arrangements for the Carnegie Institution's rights of reversion.

The Mount Wilson Institute is seeking donations to meet its goal of operating and upgrading the Observatory starting July 1, 1988. Those desiring to become a sponsor of the Mount Wilson Institute should write to: Mount Wilson Institute, 301 East Colorado Boulevard, Suite 600, Pasadena, CA 91101. Donations to the Mount Wilson Institute are tax-deductible.

Jupiter Shows Increased Disk Activity

Observers studying Jupiter in their telescopes in August, September, and early October reported that the planet is exhibiting considerable cloud feature activity, especially in the northern hemisphere.



Planet observers noted an increase in cloud activity on the Jovian disk beginning in late August and lasting through September. Visible in this photo, taken on September 5, 1987, are dark patches in the north temperate region (north is at bottom) and a faint blue loop festoon projecting across the Equatorial Zone from the North Equatorial Belt (look carefully near the center of the planet). The Red Spot Hollow (at upper left on the planet) is about to disappear around Jupiter's eastern limb. Photo by Rick Dilsizian.

Jose Olivarez, a Jupiter recorder for the Association of Lunar and Planetary Observers (ALPO), said that based on his observations as well as observer reports from other ALPO members, the planet is going through an unusually active phase. Jupiter came to opposition October 18, 1987, and displayed a disk nearly 50 arcseconds in equatorial diameter, the largest in twelve years. Throughout the first half of January, Jupiter's disk will be over 40 arcseconds in equatorial diameter. By the end of the month the disk decreases to 38 arcseconds across, still a favorable size for observing disk detail. (See "Jupiter's Best Show in Twelve Years" by Jose Olivarez, Gazer's Gazette, November 1987.)

In late August and early September a bright rift was observed in the narrow zone that separates the two dark components of the North Equatorial Belt. This rift extended around the disk for over 25° of Jovian longitude. Such a feature is nearly 30,000 kilometers long.

Blue features and accompanying plumes or festoons have also been prominent in the northern equatorial region

The Astroscope Telescope User's Manual
Star-Checking Your Edmund Telescope
GUIDE

The sky's the limit...
Astroscan® 2001
WIDE FIELD Telescope

Reach out and explore the night sky. Unique award-winning design allows you to cradle it in your arms or it glides smoothly and solidly into its table-top base. Highlights: of this scope are its extra wide 3° field and its superb light-gathering ability with large 4⅛" clear aperture to resolve panoramic vistas. Optional image erector adapts scope to view land objects. Focuses 25 feet to infinity. System is sealed to protect against dust and moisture, and is permanently collimated at the factory.

SPECIFICATIONS – Primary Mirror: 4⅛" (105mm) clear aperture f/4.2; 17½" (445mm) f.l. parabolic; Pyrex aluminized and overcoated; figured to ⅛ wave; factory precollimated and fixed. **Secondary Mirror:** Elliptical 1.5" minor axis; ⅛ wave flat; aluminized and overcoated. Diagonal support mounted to an anti-reflection coated optical window providing protection against moisture, dust and damage to optics. **Eyepiece:** 28mm e.f.l. RKE®; 45° field; standard 1¼" O.D. barrel. **Magnification:** 16X with 28mm RKE®; 75X with optional eyepieces and Barlow. **Field of View:** 3.0 degrees at 16X. **Focuser:** Positive-grip rubber roller type, 25 ft. to infinity. **Weight:** Scope weighs 10.75 lbs. Base is 2 lbs. **Body:** Special high-impact red plastic.

Astroscan® 2001: Includes telescope, base, 28mm RKE® eyepiece, finder sight, dust cap, carry strap, 10 pg. inst. book and 36 pg. sky guide. **2001 $359**

A wide assortment of accessories are also available.

For the name of your nearest Astroscan® dealer, or for a free copy of the Edmund Scientific full color catalog, call or write:
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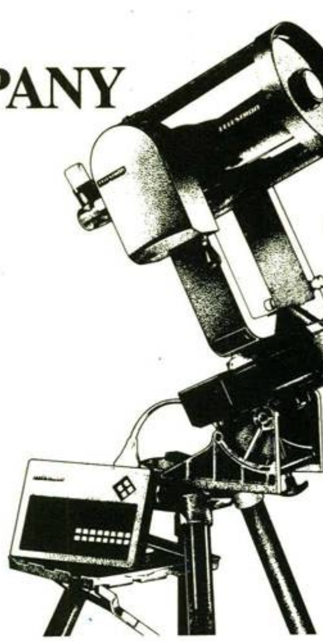

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10" Schmidt Cassegrain

2080 LX3 MCSO w/ Tripod & Wedge	**1279^{99}**
2045 Schmidt Cassegrain	**559^{99}**
2045 LX3 Schmidt Cassegrain	**799^{99}**
8800 Reflector	**829^{99}**
2080 LX5	**In Stock**
2120 LX5	**In Stock**
New 97ER Schmidt Cassegrain Spotting Scope	**389^{99}**

(MEADE 4000 SERIES PRO EYEPIECES IN STOCK)

DS-10A Deep Space Reflector	**In Stock**
DS-16A Deep Space Reflector	**In Stock**

CELESTRON
SUPER C8 PLUS
1099^{99}
w/ Tripod & Wedge

C-90 Astro Scope	**599^{99}**
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during this three-month period. Olivarez said he has observed four blue features along the northern half of the Equatorial Zone. These blue spots are thought to be holes in Jupiter's upper cloud deck.

"These spots look blue even without a filter," Olivarez said. "With a red filter [e.g., a Wratten 25] they appear black."

In addition to the blue features visible north of the Equatorial Zone, the entire northern hemisphere — usually subdued compared to the southern hemisphere —has exhibited dark and bright patches, especially in the North Polar Region.

"The amount of activity in the northern regions is unusual," said Olivarez. "That's why my attention is directed from the North Temperate Belt to the North Polar Region."

In the planet's southern hemisphere, meanwhile, the Red Spot Hollow appeared as a huge, bright oval in early October, stretching across 15° of Jovian longitude as measured through the feature's center. The Great Red Spot itself, lying inside the hollow, was light pink. Nevertheless, some observers expect the Red Spot to darken during the 1988 apparition.

4.11-Redshifted Quasar Most Distant Object

Astronomers have discovered a quasar that is to date the most distant known object in the universe. Designated Q0000-26, the quasar will permit the investigation of what matter was like when the universe was less than 20 percent its present size.

The new quasar was found last August by Cyril Hazard of the University of Pittsburgh and Richard McMahon and Mike Irwin of the Institute of Astronomy, University of Cambridge, United Kingdom, during a program to search for high-redshift quasars. They used the UK Schmidt and Anglo-Australian telescopes in New South Wales, Australia. Located near the Sculptor-Cetus border, Q0000-26 appears as a magnitude 17.5 star. Analysis of the quasar's spectrum indicates the quasar has a redshift of 4.11, corresponding to a recession speed of about 93 percent the speed of light, or nearly 279,000 kilometers per second.

Although definitive data reduction is still in progress, astrophysicists are excited by several results that have already emerged. Q0000-26 is one of the intrinsically brightest objects in the universe (as shown by its great distance and apparent magnitude). Moreover, the quasar is brighter than any of the other known quasars with redshifts around 4.0.

Analyzing the absorption lines in the spectrum of the quasar, which originate when light from the quasar passes through intergalactic matter on its way to Earth, astronomers will be able to study the structure and composition of this material in greater detail than before.

Several absorption lines in the quasar's spectrum share a redshift value even higher than that of the quasar itself. These lines are believed to be caused by matter falling toward the quasar.

The quasar's spectrum also reveals strong absorption lines from a cloud with a redshift of 3.39. Astronomers believe these lines originate when the quasar's light passes through an intervening galaxy. If true, this would confirm the presence of galaxies at these great distances and during this early period in the history of the universe.

Marswatch '88

To coordinate amateur observations of Mars and professional planetary research, members of the International Halley Watch will be discussing a program of Mars observations for the coming apparition with interested professional planetary scientists and leaders of the Mars section of the Association of Lunar and Planetary Observers (ALPO) in early February.

Stephen Edberg of the Jet Propulsion Laboratory and director of the International Halley Watch said amateur observations will be solicited after the formal meeting in February.

"We want to make sure the professional community knows what ALPO has available," said Edberg. Founded in 1947 by Walter H. Haas, ALPO is an amateur organization dedicated to the serious study of the solar system. In its forty-one-year history ALPO has accumulated one of the most extensive records of observations by nonprofessional observers in existence. These observations have many times proven valuable to planetary researchers.

Mars will be nearer to Earth in late September 1988 than it has in seventeen years, and the apparition is expected to be one of the most favorable of the century. The planet will display a disk 23.8 arcseconds across, which is just 1.3 arcseconds shy of the maximum attainable diameter observed in August 1924. Mars will also be 20° higher in the sky than it was in 1971 (the last favorable opposition), so the planet will be well placed for observers in both hemispheres.

Edberg said that until the February meeting, no definite observing goals will be made. "Basically we're waiting for the scientific counsel to meet before we announce any formal plans," Edberg said.

How Do Galaxies Form Shells?

A new study of a galaxy shell suggests that not all galaxies with shells get their shells by colliding with other galaxies, as was previously suspected. Galactic shells are enormous low surface brightness haloes of gaseous material surrounding the bright inner regions of galaxies.

NGC 474, an 11th-magnitude lenticular galaxy in Pisces, shows a diffuse, broken shell or ring of light on long exposure photographs. This light is from stars that lie extremely far away from the galaxy's center. Astronomers James M. Schombert of Caltech and John F. Wallin of Iowa State University conducted a study of NGC 474 late in 1986. The astronomers measured the surface brightness of the galaxy's shell in several colors. They found that unlike other galaxy shells, which are strongly blue in color, NGC 474's shell is strongly red. This suggests that the shell was not formed by a galaxy merger, as the blue shells apparently were.

From their observations of the NGC 474 shell Schombert and Wallin believe this shell was formed by tidal interaction between NGC 474 and a tiny neighbor galaxy designated NGC 470. Apparently confirming this is the fact that NGC 470 is visibly distorted on plates from the second Palomar *Sky Survey*.

Hot Gas Flowing from Active Galaxy

Seyfert galaxies, a class of galaxies that emit enormous amounts of energy from a compact central source, generate billions of times more energy than the Sun. For years astronomers have speculated that a by-product of this prodigious energy production would be a flow of hot gas from the central energy source. But efforts to detect such outflows have been unsuccessful, even though astronomers believed the presence of outflows to be theoretically necessary.

Now, however, two astronomers working at the National Optical Astronomy Observatories (NOAO) report they have detected immense, organized plumes of hot gas flowing from the poles of the Seyfert galaxy NGC 3516, an S0-type galaxy lying 28 megaparsecs away — one of the closest Seyfert galaxies. The plumes extend at least 1,000 parsecs from the nucleus.

Jean W. Goad of the NOAO and John S. Gallagher III, formerly of NOAO's Kitt Peak Observatory and currently director of Lowell Observatory in Flagstaff, detected the flow on a spectrogram taken December 3, 1984, during an observation with Kitt Peak's 4-meter Mayall telescope. The spectrogram revealed that light from the galaxy was Doppler-shifted by internal motions of gas. When the slit of the spectrograph was placed between 3 and 7 arcseconds from the center of the galaxy, Goad and Gallagher noted emission lines characteristic of those associated with the nucleus. This suggests that the gas in this region is flowing outward from the nucleus. However, the flow

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cannot be classified as a "jet" — a linear stream of gas seen issuing from the cores of some active galaxies — because radio emission, characteristic of classic galactic jets, has not been detected from the flow. Hence, the flow is structured similarly to a jet but doesn't possess the energy of a jet.

It is this structure, Goad said, that is the most interesting feature of the flow. "Other Seyferts have shown some symmetries, things that people call jets," Goad explained. "What is surprising here is the clarity and definition of these plumes. Often you map the velocities [of the gas] and it's just a mess. Here is something that looks organized."

The detection of this flow has fulfilled theoretical predictions about active galaxies. When astronomers realized how much energy is produced in the cores of some active galaxies, a gas outflow of some type was presumed to be a necessary consequence of that energy.

"In making an active nucleus," Gallagher said, "something has to produce huge amounts of energy, lots of hot gas, so that one expects the gas to flow out for some distance from the nucleus."

It's too soon to say whether or not this low-energy flow is typical of active galaxies. According to Gallagher, the flows may be common, but they are not large enough to be seen in the more distant Seyfert galaxies.

"We can't generalize about [the flow] yet," said Gallagher. "I think we may have caught it at a special moment in its evolution. It could possibly be part of the life cycle of an active nucleus."

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January 10-14, 1988
171st Meeting of the American Astronomical Society (professional meeting sponsored by the University of Texas at Austin and McDonald Observatory), Austin, Texas. Contact: American Astronomical Society, 2000 Florida Avenue, NW, Suite 300, Washington, DC 20009.

January 16
3rd Annual Astronomy Day (sponsored by Patterson Planetarium and Callaway Gardens), Callaway Gardens outside Columbus, Georgia. Contact: Carole Rutland Groce, Patterson Planetarium, 2900 Woodruff Farm Road, Columbus, Georgia 31907. Phone: (404) 568-1730.

January 16-17
Astronomy Weekend (telescope fair, observing, exhibits, sponsored by the Louisville Astronomical Society and the Louisville Museum of History and Science), Louisville, Kentucky. Contact: Alan Goldstein, Museum of History and Science, 727 West Main Street, Louisville, KY 40202. Phone: (502) 589-4584.

January 16-18
Stardate '88 (observers convention), Cape Egmont Observatory, New Plymouth, North Island, New Zealand. Contact: David Coppart, P.O. Box 811, Whangarel, New Zealand.

February 18-21
IAPPP Symposium: New Generation Small Telescopes, Lazy K Bar Ranch, Tucson, Arizona. Contact: Russell M. Genet, Fairborne Observatory, 1357 North 91st Place, Mesa, AZ 85207. Phone: (602) 986-2828, (602) 297-0702 for reservations.

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4th Annual Winter Star Party (sponsored by the Southern Cross Astronomical Society), Florida Keys, Florida. Contact: Tippy D'Auria, 1051 N.W. 145th Street, Miami, FL 33168. Phone: (305) 685-6001.

May 27-30
Riverside Telescope Makers Conference, Camp Oakes, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Avenue, Riverside, CA 92503. Phone: (714) 689-6893.

June 25-July 2
100th Annual Meeting of the Astronomical Society of the Pacific, jointly sponsored by the Royal Astronomical Society of Canada and the Western Amateur Astronomers, University of Victoria, Victoria, British Columbia, Canada. For registration packet (available in spring 1988) contact: A.S.P., Summer Meeting Department, 1290 24th Avenue, San Francisco, CA 94122.

July 27-30
ALCON, the 1988 Astronomical League Convention, Iowa Western Community College, near Omaha/Council Bluffs, Nebraska. Contact: George E. Allen, 3390 South 130th Street, Omaha, NE 68144. Phone: (402) 333-1097.

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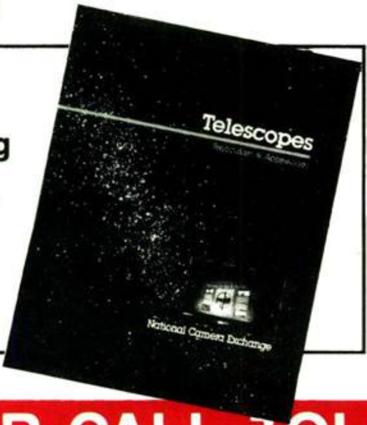

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ANNOUNCEMENT — Milwaukee Lunar Reclamation Society (MLRS), a chapter of the National Space Society, meets the second Thursday evening and second Saturday afternoon of the month. Contact MLRS, P.O. Box 2102, Milwaukee, WI 53201. Phone Peter at (414) 342-0705.

ANNOUNCEMENT — Potlatch Network is exploring star lore and the classical origins of star names. We would be interested in swapping and sharing constellation, star, and celestial folklore. Contact Potlatch Network, Lee Allen, P.O. Box 4674, Chicago, IL 60680.

ANNOUNCEMENT — The Cheyenne Astronomical Society meets the fourth Sunday of each month at 1:30 p.m. at the Laramie County Library. Two gazing parties a month — one lunar and one out of town. Monthly newsletter. Call Mike at (303) 634-2509 or Bob at (303) 637-7837.

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ANNOUNCEMENT — Morehead Planetarium at the University of North Carolina – Chapel Hill is accepting applications for a 1988-90 planetarium internship/teaching assistantship. Annual stipend is $10,000. Application deadline February 15, 1988. Contact Intern Selection Committee, Morehead Planetarium, CB# 3480 Morehead Planetarium Building, UNC–CH, Chapel Hill, NC 27599-3480.

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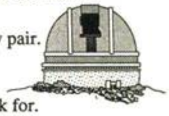

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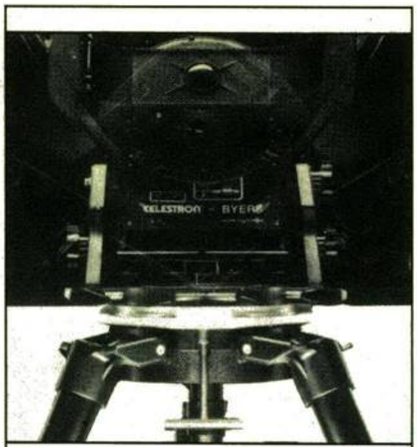

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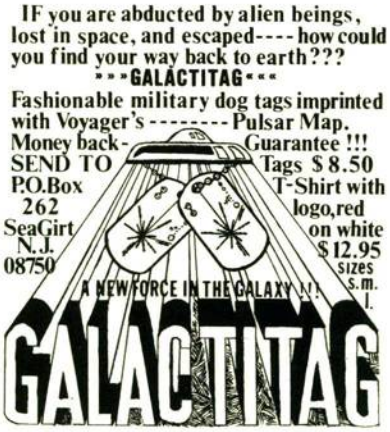
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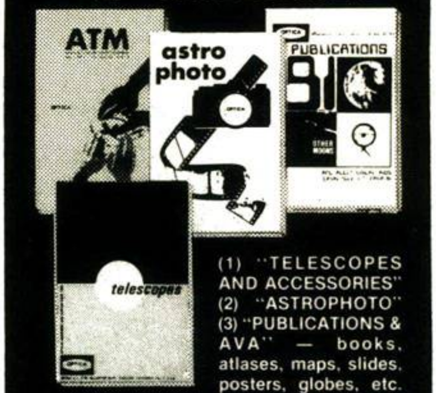

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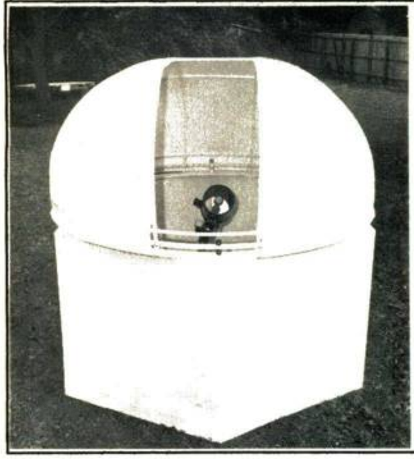

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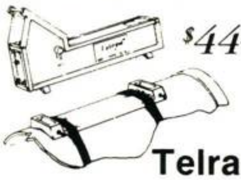

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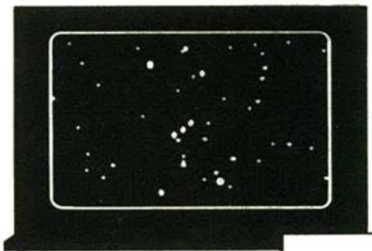

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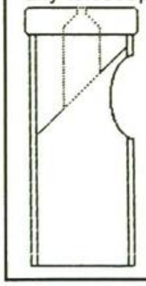

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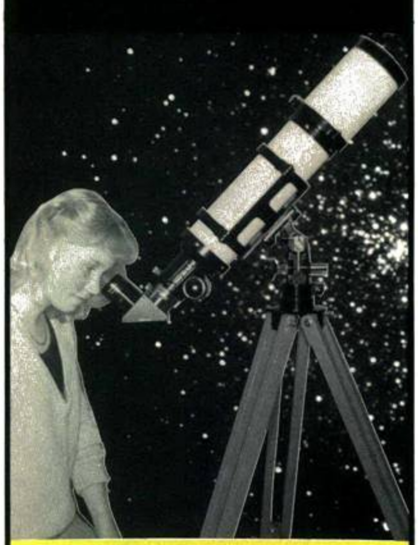

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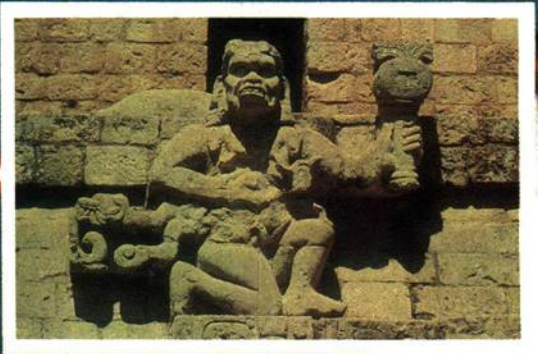

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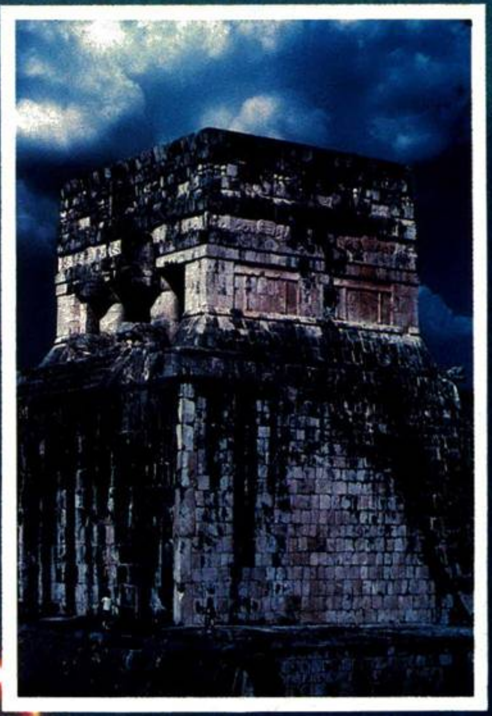

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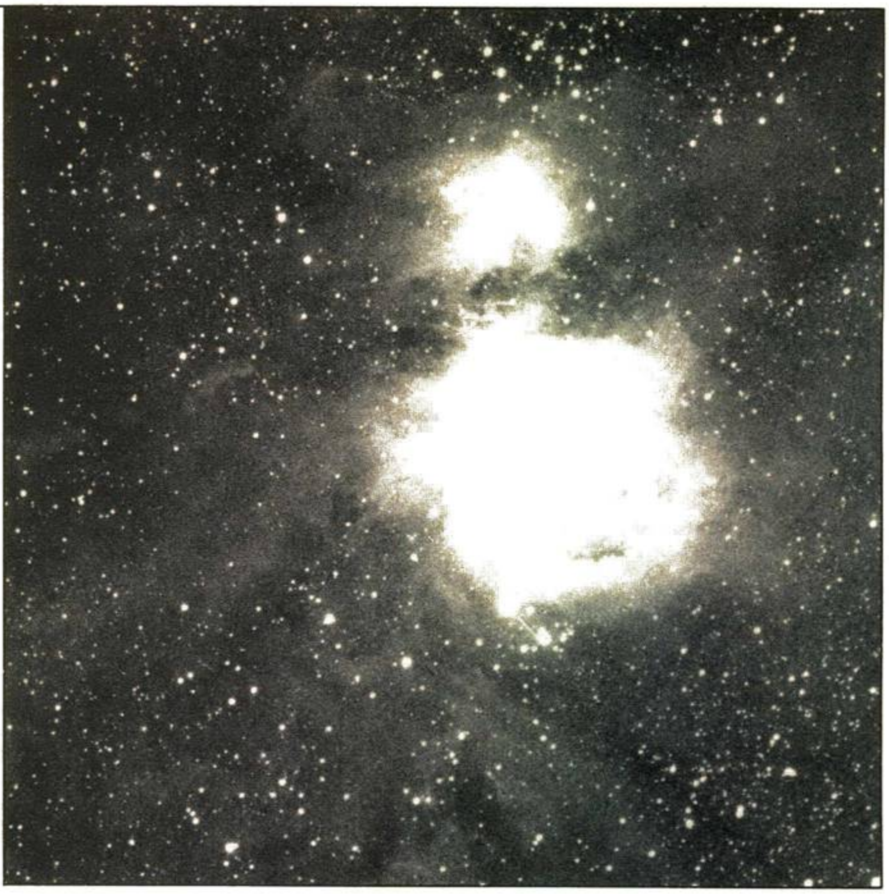
Orion's Great Nebula

Messier 42 NGC 1976



The next time you're out under the winter stars, gaze up at Orion the Hunter. You'll recognize this bright constellation by the three stars that form its belt: Alnitak, Alnilam, and Mintaka. Shift your gaze about 5° southward from the belt to a short, north-south row of three stars, Orion's sword, and look carefully at Theta (θ) Orionis, the center star in the sword. It is enveloped in a small, nebulous patch of light, which is the **Orion Nebula**, or M42 (NGC 1976), a large, bright, deep-sky object that is one of the most celebrated objects in the sky.

M42 is one piece of an extensive network of bright and dark nebulosity covering the constellation of Orion. We see the Orion Nebula because it is the brightest piece of the Orion nebular cloud; most of the other parts are too faint to observe visually. The Orion Nebula is a stunning example of an emission nebula, a region of hydrogen gas that is condensing into stars and shining by the stars it has created. This nebula glows at approximately magnitude 3.5, though the bright star Theta Orionis and a cluster of young stars embedded near its center makes M42 appear to be a magnitude brighter.

Viewed under a dark, transparent sky, the Orion Nebula is a complex and detailed object. As you move your telescope toward Theta Orionis, you'll see a circular, milky patch of light measuring several arcminutes across in your finder scope.

A 2-inch telescope shows M42's brightest part, which surrounds the Trapezium and is shaped like a squashed tin can. This central glow measures approximately 4′ by 6′ and is brightest around the Trapezium and along the components of Theta^2 Orionis. A broad dust patch cuts into the central nebulosity on the northeastern side. Because this dust lane curves inward toward the Trapezium, it was long ago dubbed the "Fish Mouth" by telescopic observers.

Larger telescopes show progressively more detail in M42. A 6-inch RFT at 25x shows a gray-green patch of light that surrounds Theta Orionis and covers about half the field of view. Just north of Theta

Opposite page: The Great Nebula in Orion (M42) is one of the brightest and largest deep-sky objects in the sky. Small telescopes do not reveal the dramatic color visible in this photo, but they do show much of the subtle filamentary structure in the nebula. Photo taken by Mike Sisk with a 24-inch Cassegrain telescope.

Above right: A long-exposure photograph of Orion's Sword shows the extent of the nebulosity surrounding M42 and the reflection nebulae just north of M42 designated NGC 1973, NGC 1975, and NGC 1977. Still longer exposures reveal that the entire Orion region is enshrouded in bright and dark nebulosity. Photo by Al Lilge, who used a 6.7-inch f/3.5 lens, 098-04 film, and a 30-minute exposure with a red filter.

Facts about M42

Type
Emission nebula containing cluster of young stars

Position
Right ascension: 5h35.4m
Declination: −5°37′
(Coordinates are for epoch 2000.0)

M42 lies in Orion's sword 5 ° south of Epsilon Orionis, the middle of three bright stars composing Orion's belt.

Magnitude
Total magnitude is approximately 3.5.

Diameter
Apparent diameter = 66′ by 60′
Linear diameter = 10 parsecs

Distance
Distance from Sun = 600 parsecs

Related Objects
Embedded in M42 is Theta^1 Orionis, a system of six stars called the Trapezium. Also lying inside M42 are the double star Theta^2 Orionis and a cluster of over three hundred dim stars near the nebula's center. Many of these stars are young, reddish variable stars. M43 (NGC 1982), a detached piece of nebulosity, lies 10′ north of M42's center. The bright star cluster NGC 1980 lies 20′ south of M42, and a complex of star clusters and nebulosity including NGC 1973, NGC 1975, NGC 1977, and NGC 1981 lies 30′ to the north.

Orionis is a small detached piece of nebulosity that appears as a small, circular glow surrounding an 8th-magnitude star. This is M43 (NGC 1982). A 6-inch scope also shows fainter sections of M42 that originate near the Trapezium and curve southward some 30′ before fading into the background sky north of Iota (ι) Orionis.

Eight-inch telescopes show a large background glow filled with sharply defined arcs of gray-green nebulosity south of the Trapezium. This size telescope also shows M43 as a blob of bright nebulosity shaped like a backward comma and the faint blue-white haze of reflection nebulae NGC 1973, NGC 1975, and NGC 1977, which are just north of the M43 region. Located north of the reflection nebulae is the large, scattered star cluster NGC 1981, a bright assemblage of stars visible in any telescope.

The largest backyard telescopes, in the 16-inch to 24-inch range, provide an amazingly detailed view of the Orion Nebula. In these telescopes, faint nebulosity surrounds the bright comma shape of M43. Many layers of milky, fluid nebulosity — each a different brightness and shade of gray-green — appear superimposed over one another. Numerous faint stars, many of which are nebular variables that appear red, pepper the inner region surrounding the Trapezium. The Fish Mouth, the dark nebula near the Trapezium, appears as a long, flattened ellipse of blackness surrounded by a field filled with bright nebulosity.

Variable Stars in and around the Orion Nebula

Designation	Magnitude Range
T	9.4↔12.6
AI	12.0↔14.2
AK	11.3↔14.0
AN	10.5↔12.1
BM	8.0↔8.7
EZ	11.2↔12.6
IU	8.8↔10.0
KS	9.9↔10.9
LL	10.9↔12.5
LP	8.4↔9.3
LQ	11.8↔13.0
LR	11.9↔13.2
LU	12.0↔13.4
LX	11.9↔13.1
MR	10.3↔12.0
MV	11.7↔13.2
MX	9.6↔10.5
NP	11.5↔12.6
NQ	11.1↔12.4
NU	6.5↔7.6
NV	9.5↔11.3
NZ	11.9↔14.2
TU	11.6↔14.0
V358	11.9↔12.4
V361	8.1↔9.8
72	11.2↔12.6

Large telescopes also show some faint outer parts of M42 normally only visible in deep photographs of the region. The American astronomer George P. Bond saw these outer nebulosities in February 1861 and remarked: "It is now impossible to see in it any other aspect than as a maze of radiating, spiral-like wreaths of nebulosity or filamentary tenticles; the centre of the vortex being about the trapezium." Today's large backyard telescopes will provide an inspiring a view of the faint nebulosity surrounding the Trapezium. At low power a 17.5-inch scope shows wings of faint light extending east and west from the Trapezium area. These extensions make M42 appear quite different from the way it appears in small telescopes. Also visible in a large scope are great loops of material streaming southward that extend beyond even a low-power field of view. Large numbers of small, faint patches of light on the outskirts of the M42 cloud become visible in large scopes, which makes this one of the sky's most complex areas.

Because most deep-sky objects have relatively low surface brightnesses, seeing color in the objects is very difficult. However, M42 is bright enough that a large telescope shows subtle shades of blue and pink throughout parts of the Orion Nebula. Detecting this subtle coloration depends not only on telescopic size but on the atmospheric conditions and, most importantly, a keen observing eye.

At the very center of the M42 glow lies Theta^1 (θ^1) Orionis, which in telescopes appears as a multiple star. Eight stars are members of this system. The four brightest stars — designated A, B, C, and D — form a trapezoid called "the Trapezium." The brightest star, C, lies on the southern end of the Trapezium and shines at magnitude 5.1. Star A lies 13.0″ northwest of C and is an eclipsing binary with a magnitude range of 6.7 to 7.7 and a period of 65.4 days. Star B, 8.8″ northeast of A, is also an eclipsing binary; it is designated BM Orionis and varies between magnitudes 8.0 and 8.7 over 6.5 days. Star D, a magnitude 6.7 object, lies 19.3″ southeast of star B.

In 1826 F. G. W. Struve discovered a fifth star in the Trapezium, a magnitude 11.5 object that became star E. This faint star lies 4.1″ north of star A. A sixth star, called star F, is located 4.0″ southeast of star E. Although glare from the four bright Trapezium stars makes E and F more difficult to see than other 11th-magnitude stars, these two stars are visible without much trouble in small scopes.

More challenging are the three faintest members of the Theta^1 Orionis group. While testing the 36-inch refractor at Lick Observatory in 1888, Alvan G. Clark discovered a 16th-magnitude star 7.0″ west of star D. This newest member of the Trapezium was designated star G. Later in the same year Edwin E. Barnard found a faint double star 7.9″ south of star A. The components of this system were designated H and H′ and glow dimly at magnitudes 15 and 16. Users of 16-inch and larger scopes may glimpse these elusive points of light with high power on nights of exceptional seeing.

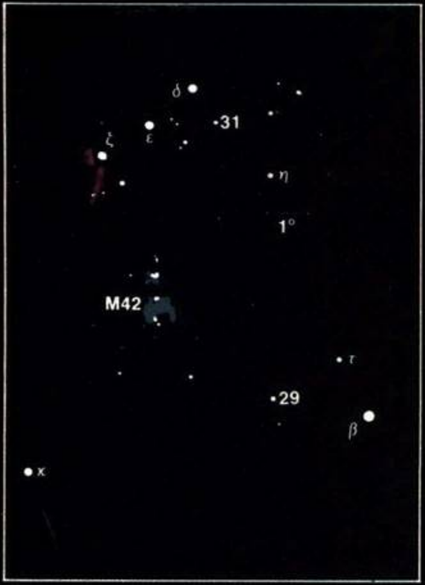
In addition to Theta^1 Orionis, the wide double star Theta^2 (θ^2) Orionis lies within the M42 nebulosity. Some 135″ southeast of the Trapezium, Theta^2 Orionis is easy to find and sports stars of magnitude 5.2 and 6.5 separated by a gap of 52.5″. This pair can be resolved with virtually any telescope and, although not challenging, its sparkling white components form a pretty sight.

The core of the Orion Nebula is filled with faint stars, as you would expect, because the nebula's gas is in the process of creating these stars. Altogether over three hundred stars brighter than 17th-magnitude lie within a 5′ radius of Theta^1 Orionis. Of these stars and hundreds more scattered across the M42 region, many dozens are variable stars. All of the Orion Nebula variables are associated with the nebula, so they are gravitationally bound together. Some of these stars, like T Orionis and V361 Orionis, are erratic flare stars that can rise in brightness unexpectedly. Most of these stars are reddish, so-called nebular variables. These are extremely young stars that have "turned on" recently (in astronomical terms) and are burning nuclear fuel in an unstable manner that produces variable light output.

With a small telescope, a careful eye, and the charts on page 105, you can follow the brightness changes in twenty-six of these variables. To do this, take the charts outside and aim your telescope at the Orion Nebula. After letting your eyes dark adapt, use the chart to find some of the comparison stars, which are normal stars of steady brightness. On the chart the magnitudes of the comparison stars with their magnitudes (in tenths) are printed beside the stars. Look at several comparison stars of different magnitudes to "calibrate" your eye and get a rough feeling for different brightnesses. Now choose a variable star you want to estimate. Carefully compare the variable's brightness with that of comparison stars that appear roughly equivalent in brightness. If you find that the variable looks slightly brighter than a magnitude 13.6 star but considerably fainter than a magnitude 13.2 star, for example, you might estimate the variable's brightness at magnitude 13.5.

Why observe variables in M42? Because it's a rare opportunity to watch the seemingly static night sky change. But even if you relax and only take in the view of M42 in a wide-field telescope, it's nice to know that such a grand spectacle of the universe is only as distant as the nearest dark sky.

— David J. Eicher


δ
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M42
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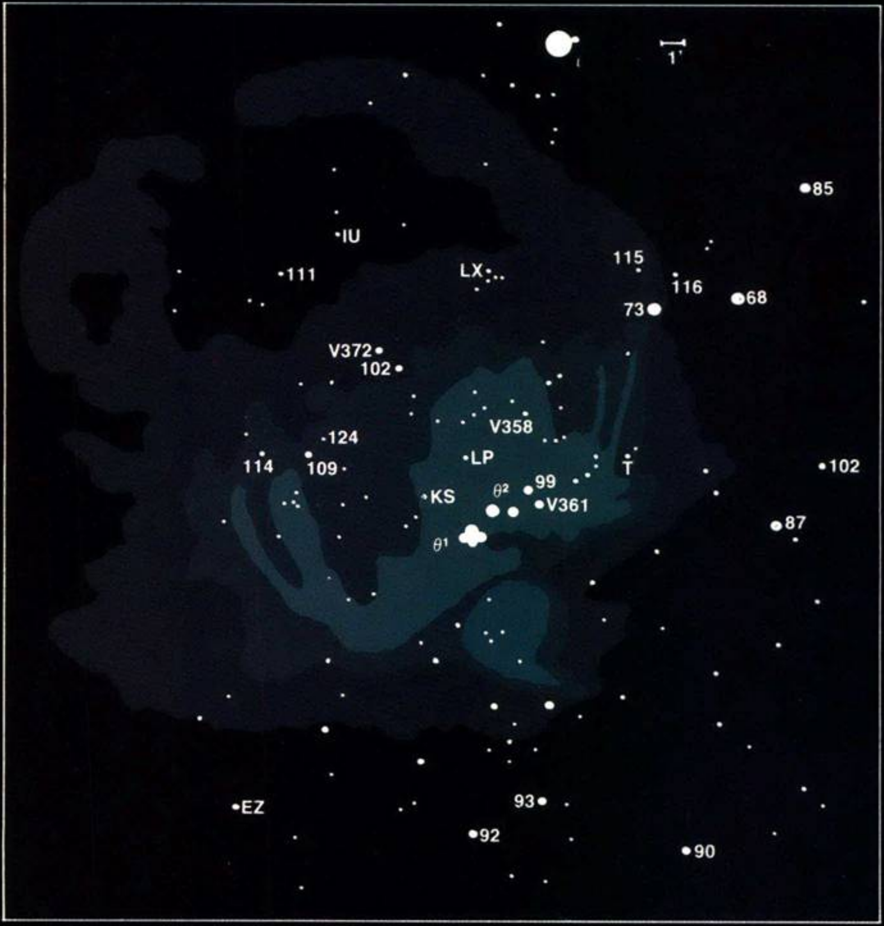
ι
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LX
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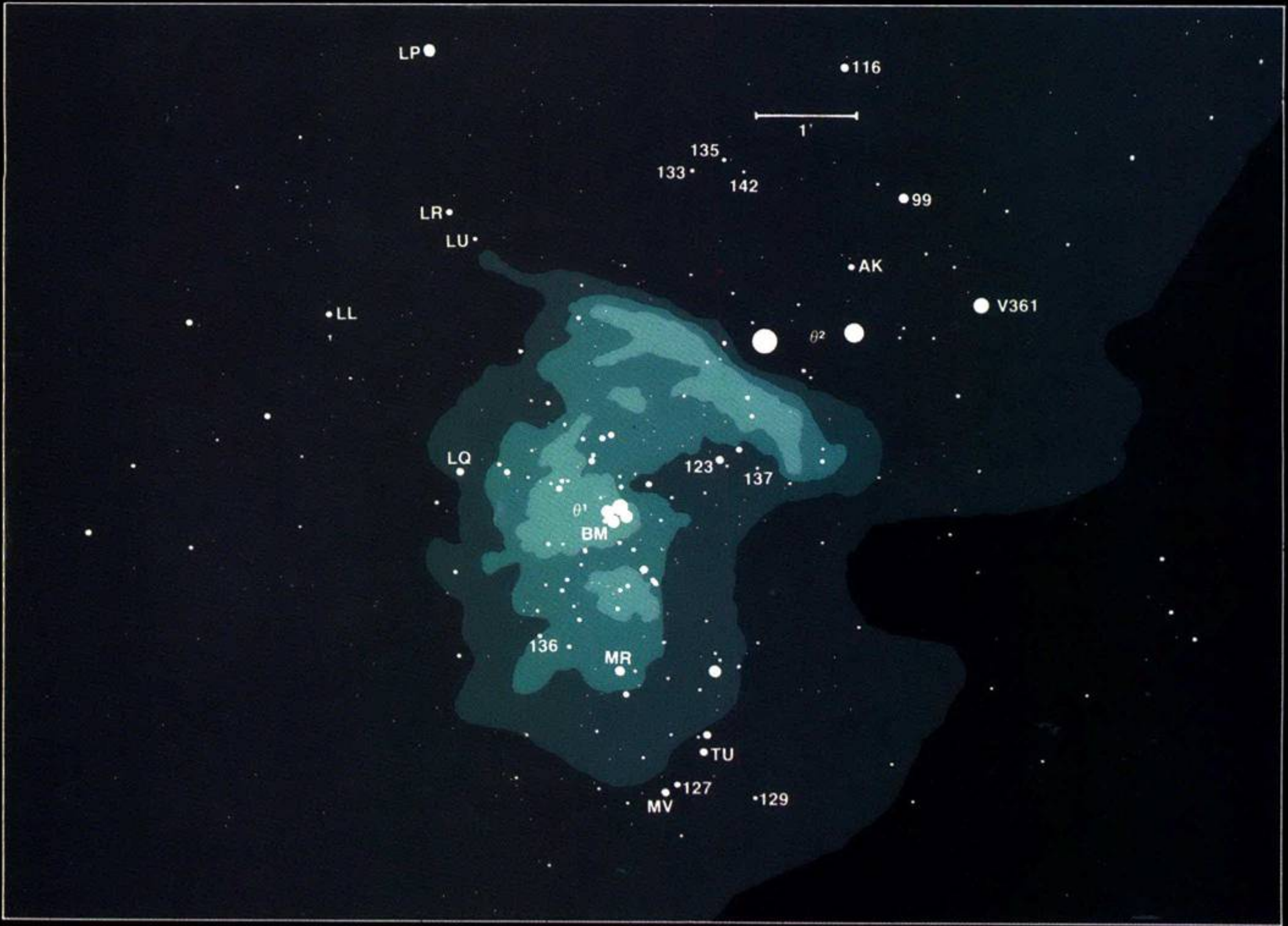
116
73
68
V372
102
V358
124
114
109
LP
T
102
KS
θ²
99
V361
87
θ¹
EZ
93
92
90

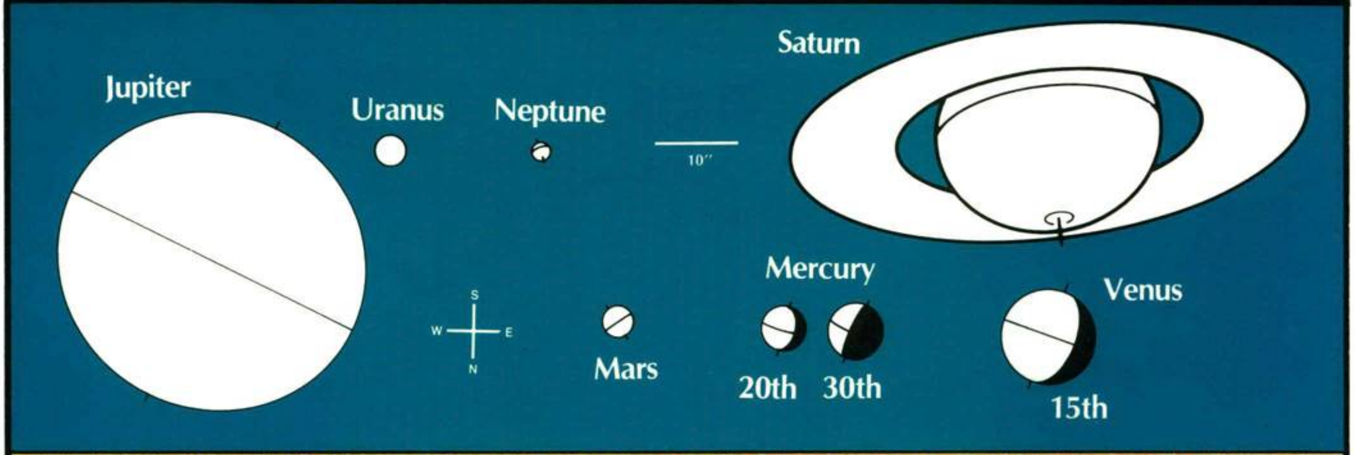
Above: M42 lies in Orion's Sword and appears as a fuzzy patch of light.

Right: This map with south at top shows bright variables in M42. Magnitudes for comparison stars are given in tenths.

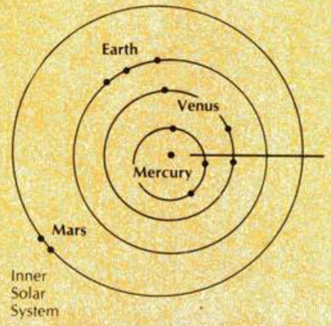
Below: In this close-up view of M42, Theta¹ Orionis lies at center and Theta² lies 2' to the southwest. South is at top. Maps by David J. Eicher.

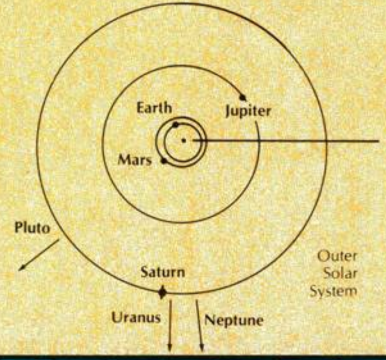

LP
116
1'
135
133
142
99
LR
LU
AK
V361
LL
θ²
LQ
123
137
θ¹
BM
136
MR
TU
127
129
MV

Planetary Data January 1988


Jupiter
Uranus
Neptune
10″
Saturn
S
W
E
N
Mars
Mercury
20th
30th
Venus
15th

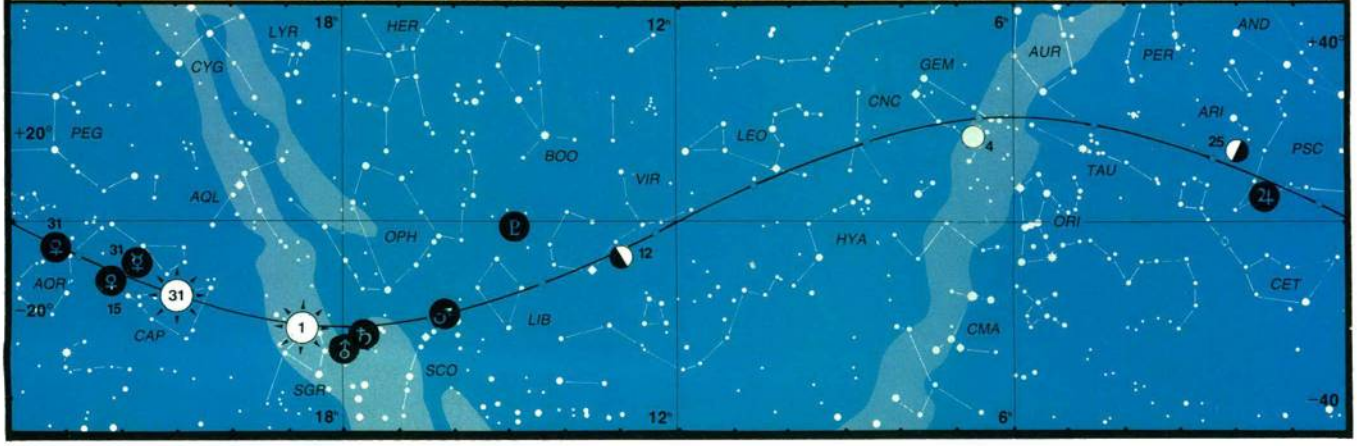
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.5′	—	0.983	—	—	279°46.8′	18h 43.3m	−23°04.2′
		15	−26.8	32.5′	—	0.984	—	—	294°02.7′	19h 44.4m	−21°16.6′
		31	−26.8	32.5′	—	0.985	—	—	310°19.5′	20h 51.8m	−17°36.8′
Mercury	☿	1	−1.0	4.8″	99%	1.410	0.441	296°19.6′	285°02.4′	19h 06.2m	−24°36.9′
		15	−0.9	5.4″	88%	1.240	0.371	347°23.7′	308°01.2′	20h 43.7m	−20°02.0′
		31	0.1	7.9″	35%	0.848	0.308	75°16.0′	327°24.8′	21h 58.2m	−11°09.7′
Venus	♀	1	−4.0	12.5″	84%	1.333	0.727	358°19.5′	312°11.0′	21h 00.7m	−18°53.1′
		15	−4.0	13.3″	81%	1.256	0.725	20°37.5′	329°20.8′	22h 08.2m	−13°13.3′
		31	−4.1	14.4″	77%	1.161	0.723	94°30.8′	348°45.4′	23h 20.3m	−5°26.0′
Mars	♂	10	1.5	4.5″	94%	2.069	1.590	213°31.5′	241°04.7′	15h 56.1m	19°59.7′
		20	1.4	4.7″	94%	1.989	1.578	218°20.9′	247°44.7′	16h 24.0m	−21°19.5′
Jupiter	♃	15	−2.4	40.1″	99%	4.911	4.963	32°45.3′	21°32.3′	1h 21.3m	7°15.2′
Saturn	♄	15	0.5	15.2″	100%	10.906	10.040	264°30.4′	267°12.9′	17h 48.0m	−22°18.1′
Uranus	⛢	15	5.8	3.5″	100%	20.134	19.252	267°13.2′	268°34.8′	17h 54.1m	−23°36.3′
Neptune	♆	15	8.0	2.2″	100%	31.174	30.229	277°48.7′	278°27.1′	18h 36.7m	−22°13.0′
Pluto	♇	15	13.7	0.1″	100%	29.954	29.672	220°25.7′	222°22.1′	14h 59.4m	−0°19.4′


Earth
Venus
Mercury
Mars
Inner
Solar
System


Earth
Jupiter
Mars
Pluto
Saturn
Uranus
Neptune
Outer
Solar
System

Moon Data

Full Moon	Jan. 4 at 1h40m
Last Quarter	Jan. 12 at 7h04m
New Moon	Jan. 19 at 5h26m
First Quarter	Jan. 25 at 21h53m
Full Moon	Feb. 2 at 20h51m
Last Quarter	Feb. 10 at 23h01m
Apogee: Jan. 7 at 5h54m	405,982 km
Perigee: Jan. 19 at 20h52m	357,509 km


LYR
18h
HER
12h
6h
AND
+40°
CYG
GEM
AUR
PER
CNC
ARI
+20°
PEG
LEO
25
PSC
BOO
4
TAU
VIR
AQL
31
OPH
HYA
ORI
31
12
AQR
15
31
CET
−20°
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LIB
CMA
CAP
SCO
SGR
18h
12h
6h
−40

Planets

Mercury

Mercury is visible in the evening sky between January 11 and February 7. The diminutive planet will maintain an elevation (forty-five minutes after sunset) of at least 5° from January 20 until February 3. Its highest elevation of around 7° and overall best visibility occur between January 26 and 30.

Viewing Mercury with a telescope can be chancy. You need an unobstructed horizon (toward the southwest in this case) and clear skies without haze or clouds. Luckily, Mercury will be easy to identify because the planet shines brilliantly at magnitude −0.6 at greatest elongation on January 26.

With your finder scope make horizontal sweeps starting at the horizon and work upward. When you think you've spotted Mercury, center it in your telescope's eyepiece. If your eyepiece isn't powerful enough to reveal a disk, swap eyepieces until you find one with sufficient magnification to show the disk.

Mercury's disk will appear 6″ or 7″ across and gibbous like a tiny, featureless Moon. Observing Mercury is fun, because Mercury moves quickly enough that changes in the shape of its disk become visible in as little as a week.

The table of Mercury elongations for 1988 at right shows this is one of the year's better apparitions, so try not to miss it.

Venus

If Mercury is hard to find, locating Venus (also in the evening sky) is laughably easy. At magnitude −4.0 this bright object is hard to miss. Between now and greatest elongation in early April Venus will move northwest and roughly maintain its current brightness.

In your telescope the white cloud tops that hide the planet's terrain are always dazzlingly bright; therefore, you may not discern right away that the illuminated disk looks gibbous. Carefully observing the planet with direct and averted vision and viewing the planet earlier in twilight will reduce the contrast between planet and sky and make Venus' shape more obvious.

Mars

Mars lies in the morning sky, where it rises three-and-a-half hours before the Sun. As twilight starts to brighten the sky, Mars is about 25° above the southeastern horizon, shining at magnitude 1.5. It will hold that elevation all month while it slips southward about 10° along the horizon.

In a telescope Mars is slightly improved this month compared to the way it's appeared over the last few months. But its disk still remains less than 5″ across, and you shouldn't expect to see more than a small ocher disk with perhaps a few faint dusky markings.

Minor Planets

1 Ceres lies too near the Sun to be seen this month; it is in conjunction on February 1.

2 Pallas (magnitude 10.4) is moving eastward across Serpens Cauda into Aquila. Its positions:

1st:	18h29m34s, 3°08.1′
10th:	18h42m20s, 3°17.0′
20th:	18h56m17s, 3°36.2′
30th:	19h09m54s, 4°04.8′

Pallas will be difficult to observe because it rises only shortly before the Sun.

3 Juno (9.7) lies in Aquarius. During the second week of January it will pass about 1° north of the three Psi (ψ) Aquarii stars. Plan to observe Juno as soon after sunset as you can, because Juno sets around 8:30 p.m. local time on the 15th. Its positions:

1st:	23h05m28s, −9°43.9′
10th:	23h21m17s, −8°32.7′
20th:	23h39m34s, −7°04.9′
30th:	23h58m32s, −5°29.4′

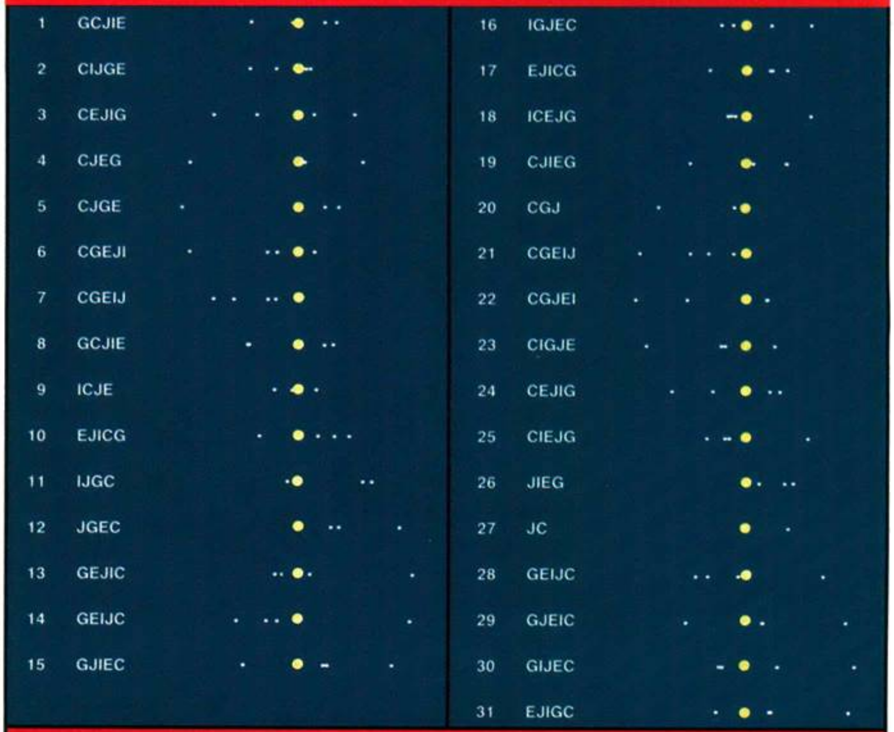
4 Vesta (6.6) is moving retrograde in Cancer and is at opposition on January 22. (Last month's Backyard Astronomer contained a diagram showing Vesta's passage near the Beehive Cluster, M44, during the first week of January.) This month Vesta is visible all night. Vesta's positions:

Elongations of Mercury and Venus — 1988

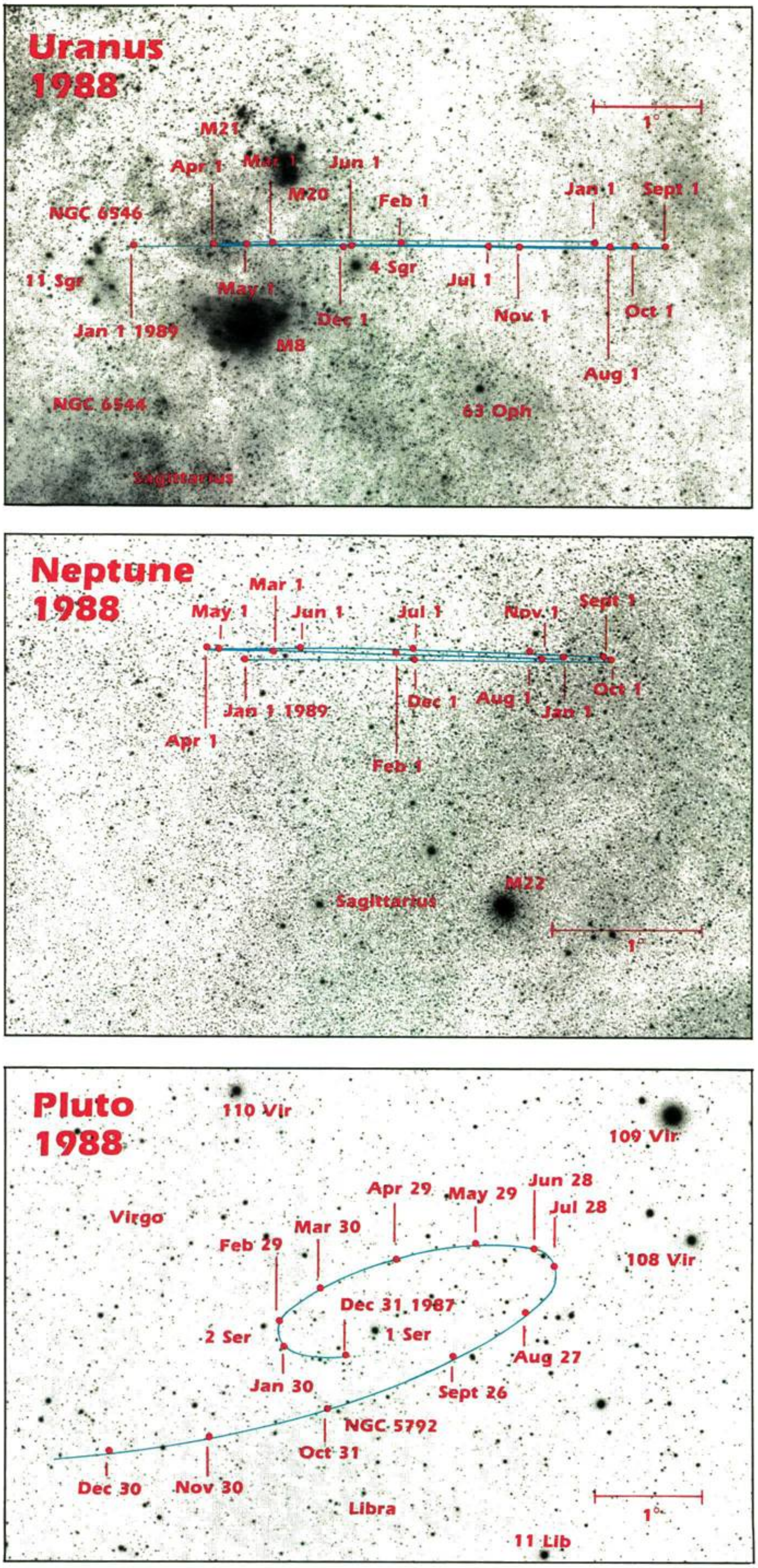
	Date	Altitude	Azimuth	Type and Extent of Elongation
Mercury	Jan. 26	7°	245°	East (evening sky), 19°
	March 8	3°	113°	West (morning sky), 27°
	May 19	11°	294°	East (evening sky), 22°
	July 6	6°	68°	West (morning sky), 21°
	Sept. 15	1°	257°	East (evening sky), 27°
	Oct. 26	9°	103°	West (morning sky), 18°
Venus	April 2	34°	273°	East (evening sky), 46°
	Aug. 22	31°	90°	West (morning sky), 46°

Altitudes and azimuths are given for forty-five minutes after sunset (eastern elongations) or forty-five minutes before sunrise (western elongations) as seen by an observer at 40° north latitude. In other latitudes the figures will vary slightly. North = 0° or 360°, east = 90°, south = 180°, and west = 270°.

Satellites of Jupiter 2h00m UT



Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)


Uranus 1988
1°
M21
Apr 1
Mar 1
Jun 1
M20
Feb 1
Jan 1
Sept 1
NGC 6546
4 Sgr
Jul 1
11 Sgr
May 1
Dec 1
Nov 1
Oct 1
Jan 1 1989
M8
Aug 1
NGC 6544
63 Oph
Sagittarius
Neptune 1988
Mar 1
May 1
Jun 1
Jul 1
Nov 1
Sept 1
Jan 1 1989
Dec 1
Aug 1
Jan 1
Oct 1
Apr 1
Feb 1
M22
Sagittarius
1°
Pluto 1988
110 Vir
109 Vir
Apr 29
May 29
Jun 28
Jul 28
Virgo
Mar 30
Feb 29
108 Vir
Dec 31 1987
2 Ser
1 Ser
Aug 27
Jan 30
Sept 26
NGC 5792
Oct 31
Dec 30
Nov 30
Libra
1°
11 Lib

These maps show the positions of Uranus, Neptune, and Pluto throughout 1988. Uranus moves back and forth between the Lagoon and Trifid nebulae. Neptune lies near globular M22 in Sagittarius. Pluto passes the galaxy NGC 5792 in Libra. Background photos courtesy Lick Observatory; maps by David J. Eicher.

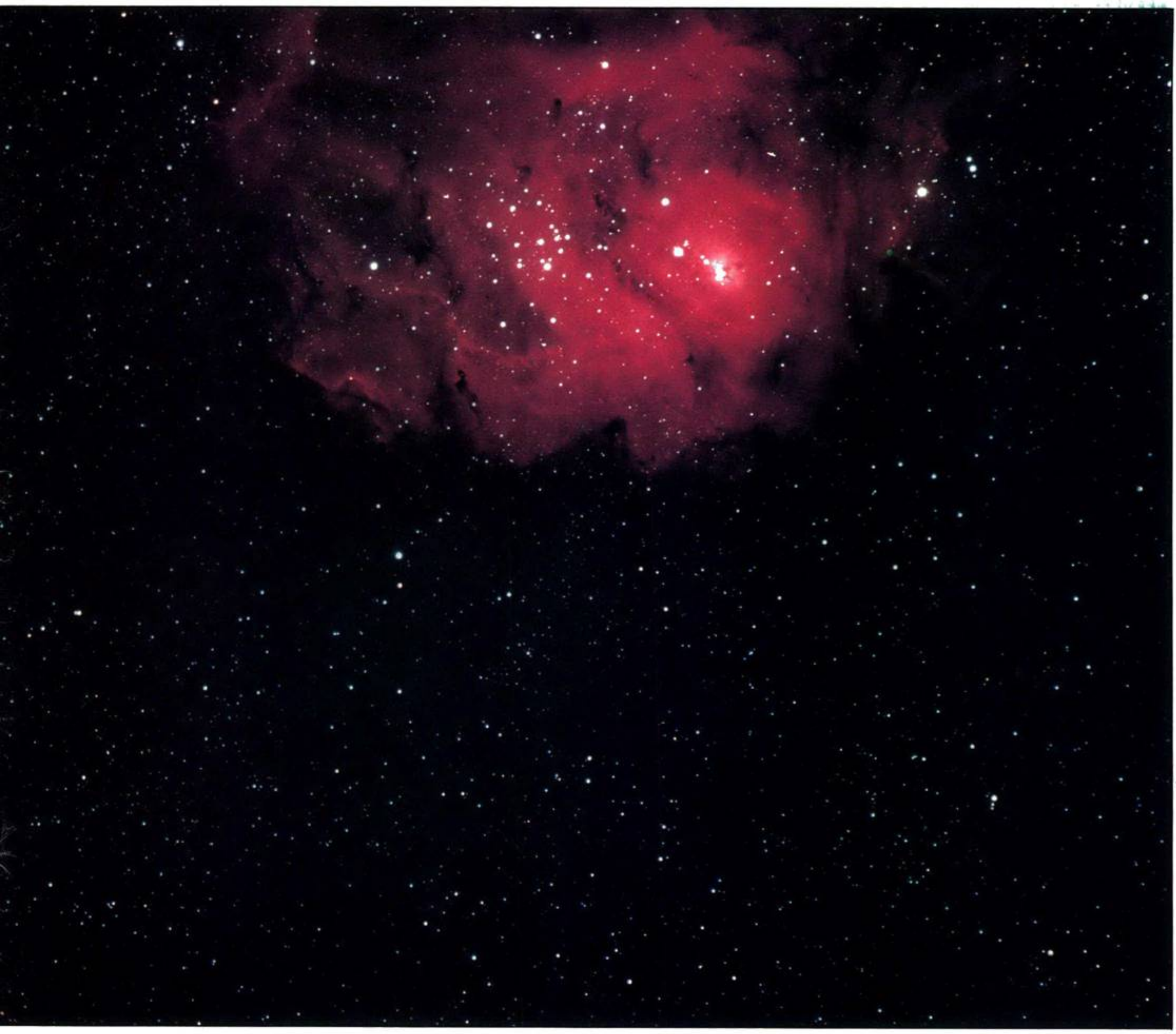
1st: 8h38m45s, 20°58.6′
10th: 8h31m14s, 21°56.3′
20th: 8h21m08s, 23°02.8′
30th: 8h10m23s, 24°04.9′

To locate a minor planet, photocopy the appropriate chart from a good star atlas (*Uranometria 2000.0* or *Sky Atlas 2000.0*, for example), plot the object's dated positions lightly in pencil, and sketch a smooth curve linking the points. (Positions are for 0h UT in epoch 2000.0 coordinates.) Then observe the starfield at low magnification and photograph or plot by hand what you see. Recheck the field a night or two later; the "star" that moved is the minor planet.

Jupiter

High in the south during evening twilight, Jupiter is as easy to see as Venus is, but telescopically Jupiter offers much more. Jupiter's clouds, unlike those of Venus, display many features.

You will see, first of all, two darkish smudges across Jupiter's middle. Because the Jovian equator runs roughly halfway



Above: Mike Sisk's photograph of the Lagoon Nebula in Sagittarius nets this month's $100 "Best Astrophoto" award. Sisk used a 24-inch f/6 Schmidt-Cassegrain telescope. Visible at lower left is the tiny globular cluster NGC 6544, which is ordinarily difficult to show resolved into stars.

between them, these are called the north and south equatorial belts. Other belts, showing faint pastel colors and ragged edges, will extend north and south of the equatorial belts about halfway to the polar regions, which always appear featureless from Earth.

The key to enjoying Jupiter is to view it for at least ten minutes every clear evening. The planet's rotation is swift enough (10 hours) that over half an hour of looking you can see changes — features near the sunrise edge become more distinct while those near the sunset limb foreshorten and disappear. (With south at top, remember the direction of rotation is from right to left.)

Saturn

Although Saturn is visible to the naked eye (magnitude 0.5) low in the southeast before sunrise on December 1, it is too low for good telescopic views. By the end of the month, however, its elevation will be 15° and conditions for viewing Saturn will improve.

Saturn's disk has as many belts as Jupiter's has, but Saturn's belts are narrower and their contrast is lower. In viewer's terms, therefore, Saturn looks bland. The rings, however, always appear crisp and sharp; this month they will span 35″. During 1988 they will tip as fully toward us — 26.9° — as they ever do.

Uranus

Although Uranus lies near Saturn in the sky, it is much more difficult to find because it is down at the threshold of naked-eye visibility. (At magnitude 5.8, Uranus is over one hundred times dimmer than Saturn.) Around the end of January center your finder scope on Saturn and then drop straight down about a degree and a half. Uranus will have a bluish green disk 3.5″ across that is easily discerned with moderate magnifications.

Neptune

Neptune is in the Milky Way east of Uranus and is a 8th-magnitude dot that is difficult to identify. A finder chart for the year is on page 108. For most of January Neptune will rise too close to the Sun to be seen, but by the end of the month its elevation (forty-five minutes before sunrise) will be about 10°. Neptune has a grayish disk 2.2″ in diameter.

Pluto

At magnitude 13.8, Pluto lies deep in "big telescope" country. To locate it, use a scope 10 or 12 inches in aperture and the finder chart on page 108. The technique is like that for a minor planet: locate the appropriate starfield and plot (by hand or photo) the objects you see. When you reobserve the field a few days later, the object that moved is Pluto. Good luck!

— Robert Burnham

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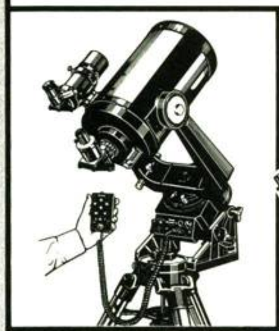
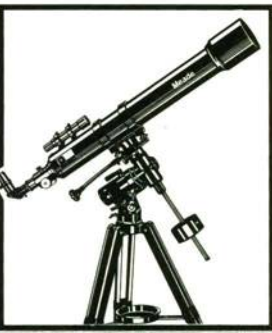
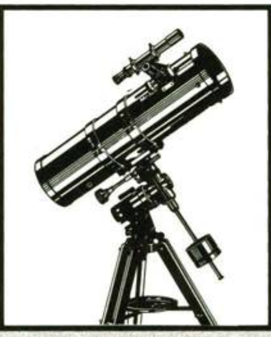
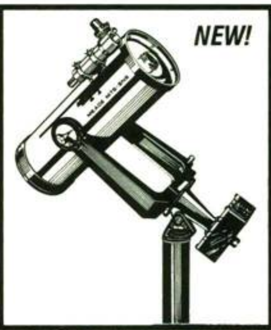
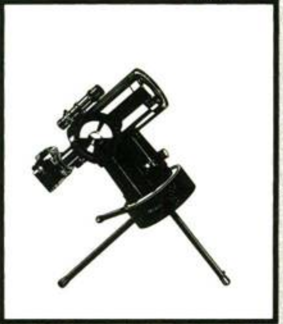







NEW!



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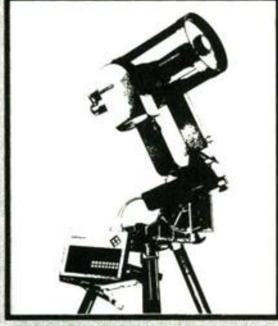

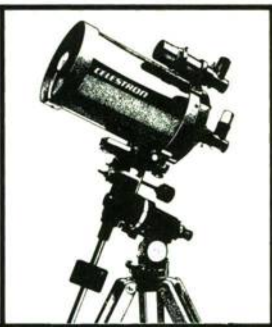

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